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Assessment of Dissolved Oxygen, Physical Habitat, and Biological Characteristics for Man-Made Canals and Unaltered Streams in Terrebonne Basin, Louisiana

Final Report

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Executive Summary

This report presents the results of a study to characterize water quality and aquatic biological resources of freshwater and estuarine water bodies in the Terrebonne Basin, Louisiana. These data were generated with the objective of providing the basis for a potentially more refined system of aquatic life use designations and water quality criteria, particularly for dissolved oxygen (DO), for the Terrebonne Basin. The study involved the collection of physical, chemical, and biological data at reference sites throughout the Basin. The study was funded by the United States Environmental Protection Agency (USEPA) Region 6 and conducted by The Cadmus Group, Inc. and ARCADIS U.S., Inc., and included the following team members: Strand Associates, Inc.; C-K Associates, LLC; E&E Group, LLC; Southeastern Pond Management, Inc.; and EcoAnalysts, Inc.

Water quality standards consist of designated uses and the physical, chemical, and biological criteria to protect those uses. In the Terrebonne Basin, all bodies of water are specified for the protection of fish and wildlife propagation and have a DO criterion of either 4 mg/L or 5 mg/L. Thirty-two bodies of water within the Basin currently do not meet the applicable DO criterion and are thus listed as impaired. However, DO levels that meet the criteria may not be possible even in the highest quality waters in the basin; therefore the current DO criteria may not be appropriate.

Fifteen reference sites, selected to represent the highest quality water bodies in the Terrebonne Basin, were chosen based upon factors such as land use, size of water body, vegetation association, and salinity. The fifteen sites were divided among freshwater, saline, and mixed salinity and different size categories were included (small stream, intermediate stream, large stream, and open water).

Four sampling events were conducted: summer 2005 (critical season), winter 2006, spring 2006 and summer 2006 (critical season). Physical, chemical and hydrological parameters were collected during all four sampling events. Biological data were collected only during the critical season. In 2005, benthic macroinvertebrates were sampled at the freshwater and mixed sites. Prior to the completion of the planned biological sampling, hurricane activity disrupted the program. In 2006, all fifteen sites were sampled for benthic macroinvertebrates and fish.

The following hydrologic parameters were measured: light penetration, water depth, water body width (for channelized streams), flow (where measurable), and GPS coordinates. Continuous monitoring equipment was used to record DO, temperature, pH, salinity, conductivity, and turbidity, with measurements taken every 15 minutes during a 48-hour period. Grab samples of water were collected for analysis of biochemical oxygen demand, total suspended solids, chlorophyll a, nutrients (nitrate, nitrite, ammonia, total Kjeldahl nitrogen, and total phosphorus). Grab samples of sediment were collected for analysis of total organic carbon and grain size.

Habitat assessment and biological sampling were performed during the critical season in 2005 and 2006. Benthic macroinvertebrates were sampled using the rapid bioassessment multihabitat approach, including the use of dip nets to sample vegetated areas and Ponar samplers to sample sediment. During the summer of 2005, only the ten freshwater and mixed sites were sampled, while all 15 sites were sampled in the summer of 2006. Fish were sampled at all fifteen sites in

2006. Electroshocking was used at the freshwater and mixed sites, while trawls and gill nets were the gear employed at the saline sites. Numbers and types of organisms collected were recorded and metrics such as species richness and diversity were calculated.

Currently, the applicable DO standard for the Terrebonne Basin is 5 mg/L for fresh water and coastal marine waters, and 4 mg/L for estuarine waters. Attainment of the DO standard is assessed by comparison of the minimum DO observed to the appropriate standard. DO at the 15 reference sites fell below the applicable standard on many occasions. Data were compiled to determine the minimum DO for each site at each sampling event, as well as the average DO. At the freshwater and mixed sites, DO excursions occurred primarily during the critical period, and the average DO fell below 5 mg/L at some time at almost all of the sites. The minimum DO was usually above 2 mg/L, but did drop even lower for one to several hours at a number of the sites. At the saltwater sites, average DO was above 4 mg/L at all sites and minimum DO was above 2 mg/L at all sites, with one exception. The percentage of time that DO values were below the applicable DO standard during the critical season was also evaluated by constructing a cumulative distribution function (CDF). The percent time that freshwater and mixed sites were below 5 mg/L was 2 to 75 percent during 2005 and 35 to 91 percent during summer 2006. The percent time that saltwater sites were below 4 mg/L was 0 to 7 percent during 2005 and 5 to 43 percent during summer 2006. Additionally, the CDF was used to define the total percent of time across all sites which were below the applicable DO standard. At the freshwater and mixed sites, the percent of time that DO was below 5 mg/L was 55 and 75 percent (using average DO) during summer 2005 and summer 2006, respectively; 100 percent of the time DO was below 5 mg/L (using minimum DO) for both years. At the saltwater sites, the percent of time that DO was below 4 mg/L was 0 percent (using average DO) during summer 2005 and 2006; 58 to 100 percent of the time DO was below 4 mg/L (using minimum DO).

Other water quality characteristics were unremarkable. It therefore appears that the selected sites do represent “least impacted” conditions, at least with respect to basic water quality parameters.

The benthic macroinvertebrate data indicated that most of the freshwater and mixed sites were characterized by a moderate or high abundance and moderate or high richness. The dominant taxa were those that could be considered tolerant of low DO. The saltwater sites were characterized by a range of conditions, from low abundance and richness in Ponar samples ranging to fairly high abundance and diversity in the dip net samples. In general, the dominant taxa at the saltwater sites were also those that could be considered tolerant of low DO.

With respect to the fish communities, the number of fish was similar across the freshwater and mixed sites, although diversity varied. Fish species that can be considered sensitive to low DO were observed at all of the freshwater/mixed sites except one. For the saltwater sites, the number of fish was also similar across sites and sensitive species were found at three of the five sites.

Bivariate plots were prepared to examine correlations between DO and species richness and diversity. DO was examined both as the average DO over the 48-hour continuous monitoring period and the minimum DO. Freshwater/mixed sites were analyzed separately from saltwater sites. None of these plots revealed any clear biologically significant relationships between DO and the biological communities that were found. In fact, the data indicates the opposite of the expected relationship. There were numerous instances where benthic species richness and diversity was higher at locations with low DO, and lower at locations with high DO. Fish species richness and diversity was also observed to be higher at locations with low DO and lower at locations with high DO.

It can be concluded that, although there is variability between the selected reference sites in the Terrebonne Basin, the majority of the selected sites supported a reasonably diverse and healthy biological community, despite the fact that DO is below the current standard. Average DO below 4 - 5 mg/L does not appear to be correlated with reductions in species richness or diversity. Minimum DO does not appear to be correlated with impacts upon biological communities either. The biological communities documented during this study appear to be compatible to historical benthic macroinvertebrate and fish data for the region. It is likely that the existing biological communities are adapted to the periods of low DO that occur during the critical season. The sites were dominated by benthos that are tolerant of low DO. Fish, being mobile, can escape from areas of temporarily low DO; thus, it is not surprising that sensitive species were found throughout the study area.

The results of the this investigation indicated that the existing DO criteria for reference locations in the waterbodies in the Terrebonne basin are not attained, especially if applied strictly as single "not to exceed" values. During the critical period, at freshwater and mixed salinity locations, the average DO did not meet the applicable standard of 5 mg/L from 55 to 75 percent of the time. At saline locations, the average DO always met the applicable standard of 4 mg/L. Approximately 90 percent of the time, the average DO was at or above 3.2 – 4.1 mg/L for the freshwater and mixed salinity sites. The average DO was at or above 4 mg/L for the saline sites 100% of the time. At the freshwater and mixed salinity sites, the minimum DO was always below the 5 mg/L standard. At the saline sites, the minimum DO was below the 4 mg/L standard more than half the time in 2005 and 100% of the time in 2006. The refinement of DO criteria, especially for those waterbodies subject to the 5 mg/L standard, and especially since criteria attainment is currently based upon the minimum DO, thus appears warranted. It is likely that multiple approaches will be required to address refinement of DO criteria in south Louisiana water bodies such as the Terrebonne basin. Potential approaches include the following:

- Use of laboratory data as a basis for the DO standard. This would require assembling available data from laboratory studies on the response of biota found in the Terrebonne basin to varying levels of DO, with verification conducted using field data obtained during this study. This approach was used to establish the saltwater DO criterion for the Virginian Province (EPA, 2000).

- Definition of a lower DO standard, potentially time dependent. The duration of exposure to low DO as well as the magnitude of DO depression are important factors to consider. The results of this study suggest that the reference locations exhibit reasonably diverse communities and that the average DO was at or above 3.2 to 4.1 mg/L approximately 90 percent of the time during the critical period at freshwater and mixed salinity sites and at or above 4 mg/L all the time during the critical period at saline sites.

- Utilization of biological assessment data to determine attainment of DO criteria including selection of indicator species and development of a biological index sensitive to DO. A preliminary evaluation of indicator species, both benthic macroinvertebrates and fish, sensitive to DO indicates that sufficient data are available for the possible development of such an index for the Terrebonne basin.

- Development of tiered aquatic life uses and corresponding DO criteria. Tiered aquatic life uses (TALUs) are bioassessment-based statements of expected biological condition in specific waterbodies. TALU, supported by appropriate criteria, can define the conditions across a continuum ranging from "totally pristine" to "completely degraded" and allow the appropriate management actions to be implemented to obtain the desired level of protection. Under the TALU approach, Louisiana could further distinguish between the "fish and wildlife propagation" use and the "limited aquatic wildlife use," adopting different DO criteria for each. The successful implementation of TALU in Louisiana would include aspects employed in other states, i.e., the use of biological information as the basis for the use designations, numeric biocriteria for each use, and development of tiers based on data from an extensive monitoring program.

Some combination of these approaches may prove most useful in refining the DO criteria for the Terrebonne basin.

1. Introduction

1.1 Background and Problem Definition

This report presents the results of a study to characterize water quality and aquatic biological resources of freshwater and estuarine water bodies in the Terrebonne Basin, Louisiana. These data were generated with the objective of providing the basis for a potentially more refined system of aquatic life use designations and water quality criteria, particularly for DO, for the Terrebonne Basin.

Water quality standards consist of designated uses and the chemical, physical, and biological criteria designed to represent measurable properties consistent with the goals specified for each use. Louisiana currently has seven types of designated uses for surface waters: primary contact recreation, secondary contact recreation, drinking water supply, oyster propagation, agriculture, outstanding natural resource waters, and fish and wildlife propagation. Within the category of "fish and wildlife propagation", a subcategory of "limited aquatic wildlife use" has been established, in recognition of the fact that some water bodies have a very uniform habitat and morphology, with low species diversity and richness, and/or a severely imbalanced trophic structure. All of the segments in the Terrebonne Basin currently include the designated use of "fish and wildlife propagation."

Water quality criteria are established to support the designated uses. Louisiana's Surface Water Quality Standards (Louisiana Administrative Code, Title 33, Part IX) include minimum criteria for DO that are to be met in fresh, estuarine and coastal marine waters. Naturally occurring variations below the criterion may occur for short periods, reflecting natural phenomena such as the diurnal fluctuation in DO resulting from photosynthesis and respiration of aquatic plants. The specified DO criteria are as follows:

- Fresh water: For a diversified population of fresh warm-water biota including sport fish, the DO concentration shall be at or above 5 mg/L

- Estuarine waters: DO concentrations in estuarine waters shall not be less than 4 mg/L at any time

- Coastal marine waters (including nearshore Gulf of Mexico): DO concentrations in coastal waters shall not be less than 5 mg/L, except when upwellings and other natural phenomena cause this value to be lower

The Terrebonne Basin includes all three types of water bodies, encompassing the three DO standards presented above. Currently, thirty-two waterbodies within the basin do not meet the applicable DO standard. However, DO levels that meet the standard may not be possible even in the highest quality waters in the basin, and therefore, the current DO standards may not be appropriate.

In this project, fifteen locations were selected to represent “least impacted” conditions representative of the specific categories of water bodies within the Terrebonne Basin. Physical, chemical, and biological data were collected at these reference sites. Originally, three sampling events were planned. However, the study area was impacted by Hurricanes Katrina and Rita in the middle of the biological sampling planned for the summer of 2005. Therefore, four sampling events were conducted: summer, 2005; winter, 2006; spring, 2006; and summer, 2006. Biological sampling was conducted only during the summer events.

This report presents introductory information in Section 1, followed by rationale for identification of reference locations in Section 2, and sampling methods in Section 3. Section 4 presents results of the data collected for the freshwater and estuarine water bodies in the Terrebonne Basin. Section 5 summarizes the project findings and provides a discussion of the results. Section 6 presents proposed approaches to refinement of DO criteria.

1.2 Project Objectives

The purpose of this project was to provide data to USEPA for potential use in refinement of the aquatic life designations and corresponding water quality criteria for DO, for freshwater and estuarine water bodies in the Terrebonne Basin. This necessitated collecting physical, chemical, and biological data from reference locations in the Basin.

The study included the following components: preparation of a Quality Assurance Project Plan (QAPP); identification of potential reference sites and classification of waterbodies in the Terrebonne Basin, Louisiana; reconnaissance of potential reference sites; final selection of fifteen reference sites; monitoring of physical and chemical parameters at fifteen reference sites; and habitat assessment and biological assessment of fifteen reference sites.

The Cadmus Group, Inc. (Cadmus), ARCADIS U.S., Inc. (ARCADIS), Strand Associates, Inc, C-K Associates, LLC (C-K), E&E Group, LLC, Southeastern Pond Management, Inc., and EcoAnalysts, Inc. conducted this project, which was funded by the United States Environmental Protection Agency (USEPA) Region 6.

1.3 Existing Data

Existing data from various sources was primarily utilized in the reference stream site selection process. Also, locations of existing data collection points was used as guidance in providing additional coverage over that accomplished by the Louisiana Department of Environmental Quality (LDEQ) in their planned sampling program. Data evaluated included information generated by LDEQ, EPA Region VI, and the U.S. Geological Survey (USGS). Available data generated by LDEQ was provided in GIS files and included data from LDEQ internal monitoring programs such as: the Ambient Water Quality Monitoring Network, various Use Attainability Analysis (UAA) Studies, the Mercury Monitoring Network, locations of point source discharges, impaired streams (303d) and the Terrebonne Atrazine project. Additionally, LDEQ provided a list of sixteen preliminary reference sites that were also mapped using GIS. Other existing data developed by Chabreck and Linscombe (1978) was incorporated into the GIS to provide generalized salinity and vegetation data. Additionally, USEPA provided land use classifications that were correlated to existing satellite imagery. USGS information on or near the reference streams was also evaluated. A GIS-based approach was utilized to integrate available data in order to focus on reference sites that met the criteria outlined in the QAPP.

Concurrent to this project, LDEQ is conducting a study in the Terrebonne Basin with the purpose of evaluating aquatic uses and DO criteria. According to the document, *Quality Assurance Project Plan (QAPP) for the Evaluation of Aquatic Life Uses and Dissolved Oxygen Criteria in the Terrebonne and Barataria Basins*, (2005) data collected for this study will include habitat assessments, continuous monitor and fish samples for the critical and possibly non-critical seasons. Continuous monitor measurements will include DO, temperature, pH, conductivity and salinity. LDEQ will attempt to obtain continuous monitor data in locations for which fisheries data currently exist or where fisheries data has historically been collected. The results of the LDEQ study are not available at this time.

1.4 Approach

1.4.1 Overview of Project

Several Tasks were identified to achieve the project objectives. First, a Quality Assurance Project Plan (QAPP) was prepared and approved. Next, a list of potential reference sites for each category of waterbody type was established. A field reconnaissance was then conducted to aid in final selection of the reference sites, establish sampling locations, and provide remaining details to finalize the sampling design. Subsequently, field sampling was performed. Physical, chemical, and hydrological measurements were conducted during a total of four sampling events. Some parameters were measured in the field, while others were analyzed by the Texas Commission of Environmental Quality (TCEQ) laboratory under an MOU with the EPA Region 6 laboratory. The field sampling also included habitat assessment and biological assessment which were conducted during the critical period in 2005 and again in 2006. Key physical and chemical water quality data were collected concurrently with the biological sampling. The results of the physical, chemical, hydrological, and biological sampling are presented and discussed in this report.

1.4.2 Identification of Project Participants and Roles

The Cadmus Group, Inc. had overall responsibility for management of the project, including schedule and budget, communication with the EPA Task Order Manager, and the quality of all deliverables. Day-to-day project management and technical oversight was provided by ARCADIS. ARCADIS was also responsible for the physical and chemical sampling and oversight of the biological sampling. Certain water quality analyses were performed by the TCEQ laboratory. Habitat assessment and benthic macroinvertebrate sampling was conducted under subcontract to ARCADIS by Strand Associates, Inc. during 2005 and by C-K Associates, LLC during 2006. Benthic taxonomy was performed by C-K Associates, LLC and EcoAnalysts, Inc. Fish sampling was performed by E&E Group, LLC, and Southeastern Pond Management, Inc., under the supervision of ARCADIS.

The project management, quality program, field sampling activities, laboratory activities, and data analysis and reporting efforts are described in the quality assurance project plan (QAPP). Duties and responsibilities of personnel for various aspects of the sampling, analysis, and reporting process were described along with an implementation schedule.

2. Identification of Reference Locations

2.1 Criteria for Reference Locations

For this project, potential reference sites are defined as those waterbodies that are least impacted by anthropogenic influences. Fifteen reference sites, representing three to four major size classes of waters, including freshwater, mixed and estuarine waters, were selected and characterized. A three-step process was used for reference sites selection: 1) identify all the available reference sites; 2) conduct field screening; and 3) final selection. Selection of reference sites was based on similar criteria used in the Terrebonne and Barataria Basins QAPP (LDEQ, 2005). These criteria included:

- Entire watershed representative of the region
- Perennial habitat (water) for an aquatic community
- Least impacted by anthropogenic influences
- Limited or no hydromodification as determined by a natural channel or bed
- No point source discharges into the waterbody
- Insignificant nonpoint source runoff
- Accessibility for sampling

2.2 Preliminary Selection

Preliminary reference sites were initially evaluated based upon a list of sixteen sites generated by the Louisiana Department of Environmental Quality (LDEQ). A GIS-based approach was utilized to integrate available data in order to focus on reference sites that met the criteria outlined in the QAPP. The primary GIS layers that were used to identify the reference waterbodies included: salinity, land use, point source discharges, and access (road and boat launch sites).

The GIS datasets used in the initial selection process were obtained from USEPA, LDEQ, and other publicly available data sources. Prior to meeting with the LDEQ, potential reference stream sites were plotted on a series of fishing maps published by Standard Maps®. These maps proved useful for planning purposes because they consisted of relatively large scale basemap that more clearly showed access and boat launches. In addition to the LDEQ reference site candidates, alternate locations were added based on the criteria listed above.

Other considerations in the preliminary reference stream site selection process included adequate coverage of physical habitat types (e.g. channel size, open water) and salinity (e.g., freshwater, mixed, or saline). (These salinity categories correspond to the system used by LDEQ). Because salinity has a crucial effect upon the resident biota, marshes are typically subdivided as freshwater, intermediate, brackish, or salt based on vegetation association rather than on salinity per se (Gosselink 1984). Although the freshwater mixed and saline categories are higher level categories, they do incorporate the characteristic marsh type associations depending upon the specific site. Preliminary sample locations on the reference waterbodies were also selected to provide additional coverage over that accomplished by LDEQ in their planned sampling program. Additionally, consultations were held with individuals having local expertise regarding potential access issues (seasonal access issues, past dredging activities, productivity, unknown discharge etc.)

2.3 Site Reconnaissance

A site reconnaissance was conducted July 19-21, 2005, in order to verify the appropriateness of the potential reference sites and to identify suitable alternative sites if necessary. A hand-held GPS was used to record the latitude and longitude at each site. In addition, all sites were marked with pink ribbon flags and notes made concerning the best way to access the site. A portable water quality meter was used to obtain selected cursory measurements at some of the sites. Observations on ambient plant and animal life, and local conditions that might impact the site were also recorded and are summarized in Table 2-1.

2.4 Final Selection

A total of 15 reference sites were selected, distributed as follows: five (5) freshwater, five (5) mixed, and five (5) saline. As stated in the approved QAPP, reference sites were selected primarily based upon land uses, discharge locations, and local expertise. In order to obtain least-impacted sites, waterbodies located in areas surrounded by agricultural, industrial, or urban land uses, or impacted by point source discharges, were not considered suitable. Accessibility was also a key consideration. An attempt was made to spread the coverage of the 15 sites across fresh, mixed, and saline water bodies (based on existing data) and various size categories (small streams/channels, intermediate streams/channels, large streams/channels, and open water). None of the selected waterbodies appear to have been recently dredged or is currently dredged. With the exception of Site C-8, which is a man-made canal, all of the waterbodies were considered natural.

Table 2-2 lists these sites and classifies them according to salinity/vegetation type and size. The sites are located on Figure 2-1. Figure 2-1 also provides land use information (e.g., forested wetland, non-forested wetland, etc), which was obtained from information provided by EPA Region 6.

A brief description of each site and the rationale for its selection follows. Sites C-1 through C-5 are freshwater, Sites C-6 through C-10 are mixed, and Sites C-11 through C-15 are saline. Selected photodocumentation obtained during the reconnaissance is attached in Appendix A. Two photographs are presented for each site, one showing the marked sampling area and one providing a broader perspective.

Table 2-1. Reference Sites in the Terrebonne Basin, Louisiana

Site	Site Coordinates	Description	LDEQ Site ID	Subsegment	Ecoregion	Observed water quality	Observed Biota	Salinity/ Vegetation Classification	Size Classification
C-1	30° 25' 14.52" N 91° 20' 38.58" W	Choctaw Bayou	Old DEQ site	120103	LMRAP	NM	River Birch, Red Maple, Black Willow, Minnows, Gar, Trumpet Creeper	Fresh	Intermediate stream
C-2	30° 13' 40.40" N 91° 24' 53.75" W	Upper Grand River just before convergence with East Atchafalaya Basin ditch	0998	120107	LMRAP	NM	Water Hyacinth, Red Maple, Cypress, Sugarberry, Cattails, Oak sp., SAVs	Fresh	Large stream
C-3	30° 12' 20.34" N 91° 22' 36.55" W	Pat Bay off Upper Grand River	2750	120107	LMRAP	NM	SAVs, Cypress, Cattails, Sugarberry, Oak, bass	Fresh	Bay/open water
C-4	30° 13' 48.43" N 91° 21' 26.06" W	Lower end of Lower Flat River just before convergence with Upper Grand River	3082	120107	LMRAP	NM	Cattails, Cypress, Red Maple	Fresh	Intermediate stream
C-5	30° 01' 47.89" N 91° 13' 13.69" W	Bay off of Lower Grand River, north of Natchez Lake	near 3081	120201	LMRAP	Temp: 32.11 ^{0}C; Cond: 252 umhos/cm; Sal: 0.12 ppt; D.O. 12.14 mg/L, pH: 8.00	Salvinia, Duckweed, Hyacinth, Alligator Weed, Black Willow, Maple, SAVs	Fresh	Large stream
C-6	29° 56' 51.50" N 91° 10' 21.86" W	Little Bayou Long/Grande Bayou	near 3079	120204	LMRAP	Temp: 30.35 ^{0}C; Cond: 391 umhos/cm; Sal: 0.18 ppt; D.O.: 1.48 mg/L; pH: 6.8	Red Maple, Water Hyacinth, Duckweed, Salvinia, Cypress, SAVs Willows, Pig Frog, Gambusia (Mosquito fish)	Mixed	Intermediate stream
C-7	29° 46' 00.23" N 91° 06' 00.07" W	Grassy Lake near Bayou Cherami	near 0588	120204	LMRAP	Temp: 31.39 ^{0}C; Cond: 348 umhos/cm; Sal: 0.16 ppt	Water Lily, SAVs, Duckweed, Salvinia, Alligator Weed, Red Maples, Cypress, Tupelo Gum, Black Willow, Alligators, Pig Frog	Mixed	Intermediate stream/open water
C-8	29° 51' 14.26" N 91° 05' 31.49" W	South Lake Verret near Norman Canal	NA	120204	LMRAP	Temp: 32.74 ^{0}C; Cond: 310 umhos/cm; Sal: 0.15 ppt	SAVs, Duckweed, Salvinia, Alligator Weed, Red Maple, Cypress - few, Sugarberry, fish jumping	Mixed	Intermediate canal/open water
C-9	29° 44' 55.07" N 91° 09' 12.89" W	Lake Palourde	Near 3111 and 3113	120205	LMRAP	Temp: 31.64^{0}C; Cond: 353 umhos/cm; Sal: 0.17 ppt	Cypress, Red Maple, Tupelo, Water Hyacinth, Phragmites, Elephant Ear, Duckweed, Salvinia, Alligator Weed	Mixed	Open water
C-10	29° 38' 05.60" N 90° 59' 58.52" W	Bay Wallace	NA	120403	CDP	Temp: 30.11 ^{0}C; Cond: 402 umhos/cm; D.O.: 0.88 mg/L; pH: 6.83; Sal: 0.19 ppt	Contiguous Cypress Swamp, Alligator Weed, Pennywort, Water Hyacinth, Duckweed, Salvinia, Gum Tree, Arrow Plant, Pig Frog (Rana grylio), Alligators	Mixed	Small stream/bay
C-11	29° 21' 36.94" N 90° 31' 33.03" W	Bayou Tambour	NA	120704	CDP	Temp: 30.77 ºC; Cond: 25620 umhos/cm; D.O.: 5.3 mg/L; pH: 7.6; Sal: 19 ppt	Spartina sp., Juncus sp. , Adinia sp. (killifish), Uca sp., Sesarma sp., Grass Shrimp, Marsh Periwinkle	Saline	Intermediate stream
C-12	29° 19' 28.21" N 90° 23' 37.40" W	Jude's Cut	NA	120706	CDP	Temp: 30.45 ^{0}C; Cond: 27680 umhos/cm; D.O.: 3.08 mg/L; pH: 7.4; Sal: 17ppt	Spartina, Juncus, Marsh Periwinkle, Grass Shrimp, Sesarma, Mysids, Geukensia shell, Adinia xenica (killifish), Mullet	Saline	Intermediate stream
C-13	29° 14' 46.93" N 90° 46' 38.87" W	Bayou Platt (Four Island Bayou area)	NA	120701	CDP	Temp: 31.86 ºC; Cond: 24280 umhos/cm; D.O.: 4.31 mg/L; pH: 7.11; Sal: 12.75 ppt	Spartina sp. 1 and sp. 2, Juncus sp., Mytilopsis leucophaeta, Adinia sp.	Saline	Intermediate stream
C-14	29° 18' 32.04" N 90° 54' 34.98" W	Fred Bayou (off of Bayou Dularge, into Mud Lake, then up into Fred Bayou)	near 3086	120703	CDP	NM	Menidia, Mullet, Neritina reclivata, mysids, Palaemonetes, Rhithropanopeus, Gammarus, Odonata, Rangia shell (dead), Oyster shell (dead), Spartina, Juncus sp.	Saline	Intermediate stream
C-15	29° 16' 57.12" N 90° 52' 54.36" W	Off of Bayou Dularge	near 3087	120701	CDP	Sal: approx. 15 ppt	Penaeus, Rhithropanopeus, Callinectes, Uca, Corophium, Gastropods, Spartina, Juncus sp.	Saline	Large stream

NM = Not measured
LMRAP = Lower Mississippi River Alluvial Plain; CDP = Coastal Deltaic Plain

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Table 2-2. Classification of Reference Sites

Site	Description	Classification	
		Salinity/vegetation[1]	Size
C-1	Choctaw Bayou	Freshwater	Intermediate stream
C-2	Upper Grand River	Freshwater	Large stream
C-3	Pat Bay	Freshwater	Bay/Open water
C-4	Lower end of Lower Flat River	Freshwater	Intermediate stream
C-5	Bay off of Lower Grand River	Freshwater	Large stream
C-6	Little Bayou Long/Grande Bayou	Mixed	Intermediate stream
C-7	Grassy Lake	Mixed	Intermediate stream/open water
C-8	South Lake Verret	Mixed	Intermediate canal/open water
C-9	Lake Palourde	Mixed	Open water
C-10	Bay Wallace	Mixed	Small stream/bay
C-11	Bayou Tambour	Saline	Intermediate stream
C-12	Jude's Cut	Saline	Intermediate stream
C-13	Bayou Platt	Saline	Intermediate stream
C-14	Fred Bayou	Saline	Intermediate stream
C-15	Off of Bayou Dularge	Saline	Large stream

[1] Salinity ranges are: 0 to 0.5 ppt for freshwater; 0 to 10 ppt but with tidal influence for mixed; ≥ 10 ppt for saline

<u>Site C-1, Choctaw Bayou</u>

This site is a freshwater site accessible from the boat launch at the end of LA highway 989. The area is a forested wetland. Tree species observed in the area included river birch (*Betula nigra*), red maple (*Acer rubrum*), and black willow (*Salix nigra*). There were no cypress trees or stumps. The area appears to have been logged. There was some bank sloughing and evidence of disturbance of the riparian habitat (although the disturbance was not recent). Several different species of minnows and a gar (family *Lepisosteidae*) were observed in the water. This site is an intermediate-sized stream. Field observations indicate that little available habitat is found at this site. The banks of the bayou appeared scoured and represented primarily clay substrate. Based on the drop in water depth, this bayou was possibly dredged in the past.

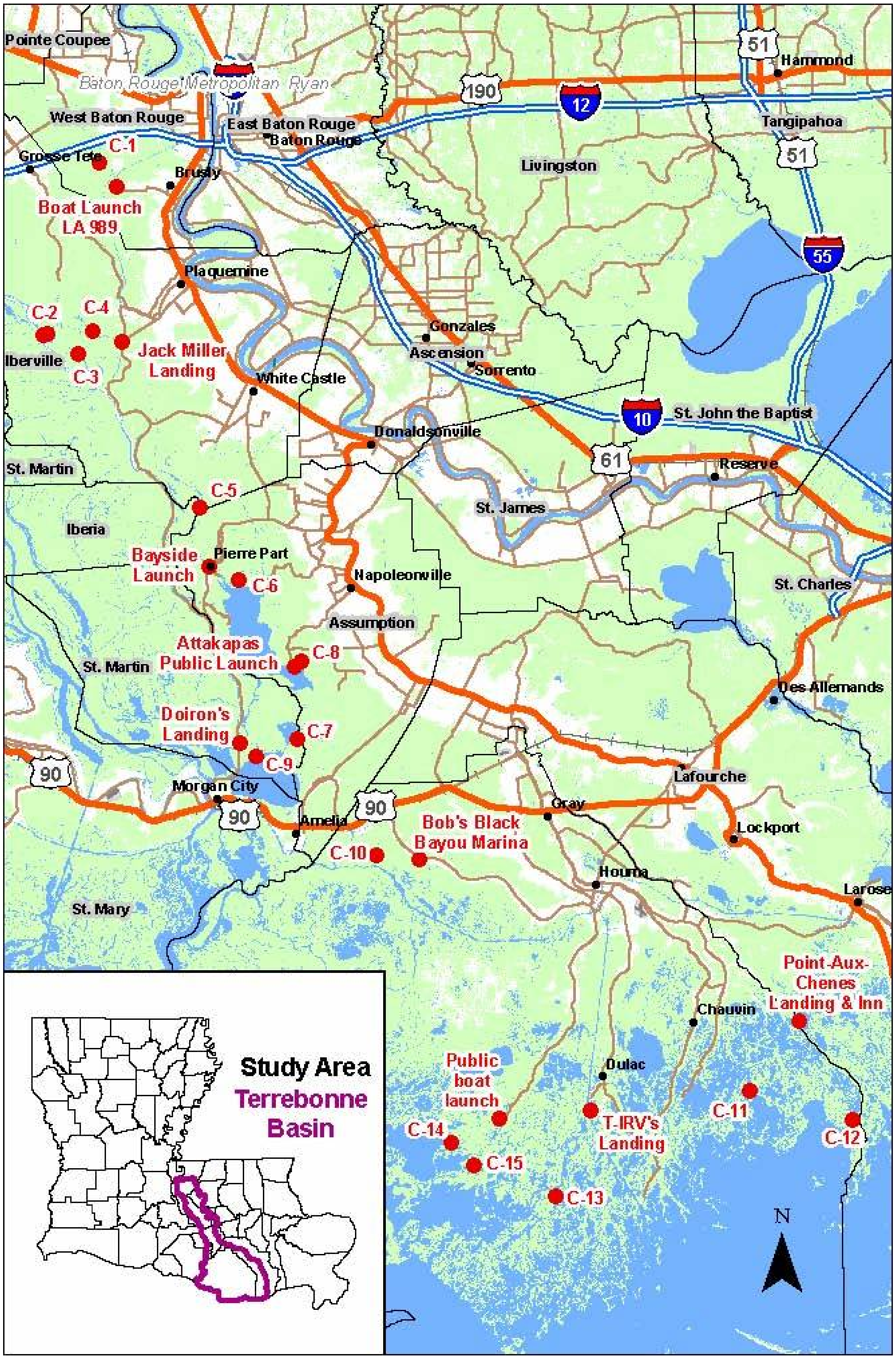

Figure 2-1. Location of Reference Sites

Site C-2, Upper Grand River

This freshwater site is in the Upper Grand River just before the convergence with the East Atchafalaya Basin borrow ditch. It is accessible from Jack Miller Landing off of Highway 75. This site is also designated as LDEQ Site 0998. A large area to the left of the site was cleared and surrounded by a chain link fence. There were also a few hunting/fishing camps in the area. Although these factors indicate potential impact, this site was retained in order to provide overlap with the LDEQ sampling program. The site is a large-sized stream. Plant species observed in the area included water hyacinth (*Eichornia crassipes*), cattails (*Typha* sp.), cypress (*Taxodium distichum*), red maple (*Acer rubrum*), oak (*Quercus* spp.), and sugarberry (*Celtis laevigata*). This area is considered forested wetland.

Site C-3, Pat Bay

Pat Bay is off the Upper Grand River. This freshwater site, LDEQ site 2750, is accessible from Jack Miller Landing. The area is considered forested wetland. Observed plant species included cypress (*Taxodium distichum*), oak (*Quercus* sp.), sugarberry (*Celtis laevigata*), cattails (*Typha* sp.), and submerged aquatic vegetation. Bass were also observed. This site is considered bay/open water.

Site C-4, Lower Flat River

This freshwater site, LDEQ Site 3082, is at the lower end of the Lower Flat River just before it empties into the Upper Grand River. Flow was observed at this site, and vegetation included cattails (*Typha* sp.), cypress (*Taxodium distichum*), and red maples (*Acer rubrum*). This site is accessible from Jack Miller Landing. This site was selected to replace the original C-4 site selected by the project team which was located in Bayou Sorrell and, upon field reconnaissance, was considered to be too impacted by hunting/fishing camps and industrial land use to be a reference site. This site is considered an intermediate stream. Land use in the area is a forested wetland.

Site C-5, Bay off of Lower Grand River, north of Natchez Lake

This freshwater site is accessible from the boat launch at Bayside Marina, Pierre Part. It is in a forested wetland area. Observed plants included *Salvinia* sp., duckweed (*Lemna* sp.), water hyacinth (*Eichornia crassipes*), alligator weed (*Alternanthera philoxeroides*), black willow (*Salix nigra*), red maple (*Acer rubrum*), and submerged aquatic vegetation. The DO reading at this site was unusually high and is believed to reflect problems with the D.O. meter. This large stream site was selected to replace the original C-5 site (LDEQ site 3081), which was inaccessible despite several attempts at various access points. The entire bay at the LDEQ site was choked with water hyacinth and was very shallow.

Site C-6, Little Bayou Long/Grande Bayou

This site is in the vicinity of LDEQ site 3079. The location of the LDEQ site was in a very shallow area and appeared to be potentially impacted by a wastewater treatment plant which was visible on the aerial map. The selected site is close to the LDEQ location but less likely to be impacted. It is accessible from the boat launch at Bayside Marina, Pierre Part. This site is classified as mixed based upon average salinity and vegetation type, notwithstanding the low salinity reading obtained on the sampling date. (This is also true for the other mixed salinity sites). A low DO reading was also obtained, but this is believed to reflect problems with the DO meter. Observed biota included red maple (*Acer rubrum*), water hyacinth (*Eichornia crassipes*), duckweed (*Lemna* sp.), *Salvinia* sp., cypress (*Taxodium distichum*), willow (*Salix* sp.), submerged aquatic vegetation, pig frog (*Rana grylio*), and mosquito fish (*Gambusia* sp.). This site is described as an intermediate stream. Land use in this area is forested wetland.

Site C-7, Grassy Lake
This intermediate stream/open water site is near LDEQ site 0588. It is accessible from the boat launch at Doiron's Landing off of Highway 70. Land use in the area is forested wetland. Observed biota included red maple (*Acer rubrum*), black willow (*Salix nigra*), cypress (*Taxodium distichum*), tupelo gum (*Nyssa aquatica*), submerged aquatic vegetation, water lily (*Nymphaea* sp.), duckweed (*Lemna* sp.), *Salvinia* sp., alligator weed (*Alternanthera philoxeroides*), alligator (*Alligator mississipiensis*), and pig frog (*Rana grylio*). In consideration of vegetation types and average salinity, this site is classified as mixed salinity.

Site C-8, South Lake Verret
This site was selected as a replacement for the original Site C-8 in Bayou Copasaw (LDEQ site 3007), based upon information from local individuals that Bayou Copasaw is and has been heavily impacted by the oil and gas industry. In addition, a review of maps indicated that there were no sloughs or natural areas off the main channel suitable for sampling. Thus, an alternate site in lower Lake Verret was selected. This site is accessible from the Attapakas Public Boat Launch. Observed plants included submerged aquatic vegetation, duckweed (*Lemna* sp.), *Salvinia* sp., alligator weed (*Alternanthera philoxeroides*), red maple (*Acer rubrum*), a few cypress trees (*Taxodium distichum*), and sugarberry (*Celtis laevigata*). Fish (mullet, *Mugil cephalus*) were observed jumping out of the water. This site is classified as mixed salinity / intermediate canal / open water. Area land use is forested wetland.

Site C-9, Lake Palourde
This site, in a forested wetland area, is accessible from the boat launch at Dorion's Landing off of Highway 70. It is a mixed salinity / open water site. Plant species observed included cypress (*Taxodium distichum*), red maple (*Acer rubrum*), tupelo (*Nyssa* sp.), water hyacinth (*Eichornia crassipes*), *Phragmites* sp., elephant ear (*Colocasia*), duckweed (*Lemna* sp.), *Salvinia* sp., and alligator weed (*Alternanthera philoxeroides*).

Site C-10, Bay Wallace
This site, a large slough in Bay Wallace, is accessible from the boat launch at Bob's Black Bayou Marina. The water is shallow in the upper reach of the slough and the habitat is exceptional. This is a contiguous cypress swamp with numerous other plants including alligator weed (*Alternanthera philoxeroides*), pennywort (*Hydrocotyle* sp.), water hyacinth (*Eichornia crassipes*), duckweed (*Lemna* sp.), *Salvinia* sp., sweet gum (*Liquidambar styraciflua*), and arrow arum (*Peltandra virginica*). Pig frogs (*Rana grylio*) and alligators (*Alligator mississippiensis*) were also observed. This site is classified as mixed salinity / small stream / bay.

Site C-11, Bayou Tambour
This site, LDEQ site 3089, is accessible from the Pointe-Aux-Chenes Launch, Store, and Inn. This is a saline site in an intermediate-sized stream. Plants observed at this site included *Spartina* sp. and *Juncus* sp; animals included grass shrimp (*Palaemonetes* sp.), marsh periwinkle (*Littoraria irrorata*), *Adinia xenica* (killifish), *Uca* sp. (crabs), and *Sesarma* sp. (crabs). There is likely more freshwater influence here than at C-12. The land use in this area is non-forested wetland.

Site C-12, Jude's Cut
This site is accessible from the Pointe-aux-Chenes Launch, Store, and Inn. This site is classified as saline / intermediate stream and is in a non-forested wetland area. Observed flora included *Spartina* sp. and *Juncus* sp., while observed fauna included marsh periwinkle (*Littoraria irrorata*), grass shrimp (*Palaemonetes* sp.), *Sesarma* (crabs), mysids (*Mysidaceae*), *Geukensia* shell (ribbed mussel), *Adinia xenica* (killifish) and mullet (*Mugil* sp.).

Site C-13, Bayou Platt
This site is accessible from the launch in Dulac at T-IRV's. The site is classified as saline / intermediate stream. Observed biota included two species of *Spartina*, *Juncus* sp., *Mytilopsis leucophaeta* (bivalve mollusk), and *Adinia xenica* (killifish). The land use in the area is non-forested wetland.

Site C-14, Fred Bayou
This site is off of Bayou Dularge, into Mud Lake, and up into Fred Bayou. It is accessible from the public boat launch at the end of Highway 315. This site was selected to replace the original C-14 site in Lake Penchant which was considered to be too fresh based upon the observations of water hyacinth and other freshwater aquatic plant species. Biota observed at the site included *Menidia*, mullet, *Neritina reclivata* (snail), mysids, *Palaemonetes* (grass shrimp), *Rhithropanopeus* (crab), *Gammarus* (amphipod), Odonata (dragonflies), *Rangia* (clam) shell (dead), *Crassostrea* (oyster) shell (dead), *Spartina*, and *Juncus* sp. This site is classified as saline / intermediate stream. Land use in the area is non-forested wetland.

Site C-15, Off of Bayou Dularge
This site is near LDEQ site 3087 and is accessible from the public boat launch at the end of Highway 315. It is near Sister Lake and the Louisiana Department of Wildlife and Fisheries (LDWF) Camp and Field Office. It is classified as saline / large stream. Land use in the area is non-forested wetland. Organisms observed at the site included *Penaeus* (shrimp), various crabs (*Rhithropanopeus, Callinectes, Uca*), *Corophium* (amphipod), gastropods, two species of *Spartina*, and *Juncus* sp.

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3. Sampling Methods and Materials

This section details the methods and materials used to collect water quality and biological data for the study. Further details on sampling methodology and quality control are located in the USEPA-approved Quality Assurance Project Plan (QAPP) (EPA, 2005; EPA, 2006a; EPA, 2006b). Samples were collected during four sampling events. The first sampling event occurred during the critical period in 2005, which, as defined by USEPA, is July 1 - September 30. The critical period typically occurs during the summer months and reflects the conditions of the lowest flow and highest temperature (as defined by LDEQ, temperature greater than 25 °C that normally result in the lowest DO concentrations). Sampling took place from August 15 to August 28, 2005. The second sampling event (winter period) occurred from January 16 to January 26, 2006. The third sampling event (spring period) occurred from April 17 to April 25, 2006. The last sampling event was during the critical period of 2006 and occurred from July 31 to August 9, 2006. Sampling for physical, chemical, and hydrological parameters during the critical period was conducted approximately one week offset from the biological sampling in order to avoid water quality impacts that could potentially be caused by biological sampling methods. Table 3-1 lists the parameters that were sampled during each event.

Table 3-1. Parameters Sampled during Each Sampling Event

Event	Dates	Parameters
Event A: Summer (Critical Period), 2005	August 15 – August 28	Physical, chemical, hydrological, biological (habitat assessment and benthic macroinvertebrates at Sites C-1 – C-10)
Event B: Winter, 2006	January 16 – January 26	Physical, chemical, hydrological at Sites C-1 – C-15
Event C: Spring, 2006	April 17 – April 25	Physical, chemical, hydrological at Sites C-1 – C-15
Event D: Summer (Critical Period), 2006	July 31 – August 9	Physical, chemical, hydrological, biological (habitat assessment, benthic macroinvertebrates, and fish at Sites C-1 – C-15)

3.1 Physical, Chemical and Hydrological Parameters

3.1.1 Hydrological Parameters

Data related to the channel geometry were collected during all four sampling events for the purpose of characterizing the waterbody and for estimating the discharge at the sampling location. Hydrologic data were collected at the selected reference sites and include the following:

- Stream width (on channelized waterbodies)
- Depth
- Flow (where measurable)
- Light Penetration (using Secchi Disk)
- Location (using Global Positioning Systems)

Width information for some of the wider streams was collected using GPS to measure the distance between the right and left descending banks. Depths were measured using a calibrated wading rod to obtain the average channel depth. Flow measurements were made where possible (e.g., in wadeable streams with acceptable bottom conditions) according to standard operating procedures, as described in the QAPP. This involved the use of established USGS methodology using a flow meter mounted on a wading rod. Stream velocity measurements were obtained at twenty evenly spaced intervals across the channel. Depth measurements were obtained at each of the velocity measurement locations. Velocity readings (or the number of revolutions per time interval) were obtained at 0.6 times the depth up from the bottom (when depth <2.5 ft) and 0.2 and 0.8 times the depth up from the bottom (when depth >2.5 ft) in order to obtain velocity measurements throughout the water column. Flow values were multiplied by the cross sectional area of the section to calculate the stream discharge.

In open waters or other locations where it was not feasible to measure velocity and flow accurately, qualitative observations were made. In these cases, surface flow measurements were estimated either qualitatively by using a floating object and a stop watch or quantitatively through visual observation. Depth measurements were made using a wading rod at approximately three or four locations across the channel in an effort to estimate the average channel depth. Light penetration values were measured using a Secchi disk. GPS coordinates were obtained using an instrument within 3 meter accuracy and expressed in terms of latitude and longitude.

3.1.2 Continuous Monitors

Measurements of DO, temperature, pH, conductivity, salinity and turbidity were made at each reference site during four sampling events: critical period 2005, winter 2006, spring 2006, and critical period 2006. These measurements were accomplished by the use of continuous monitoring equipment (datasondes) using a YSI 6920 at each site. The continuous monitors were placed in well-mixed areas at pre-selected locations on the reference waterbodies. If hydrologic conditions allowed, datasondes were placed at locations on the reference waterbody where DEQ has not planned to sample in order to extend data coverage on the selected reference waterbody. If the water depth was greater than 2 meters, the datasondes were deployed to collect samples at a depth of 1 meter. If the water depth was less than 2 meters, the datasondes were deployed to collect samples at one-half the water depth. Measurement of bottom salinity was not considered applicable based on insignificant differences in discrete measurements and shallow water depths. Diurnal field measurements were made over a 48-hour period for DO, temperature, conductivity, salinity, pH, and turbidity.

3.1.3 Grab Samples for Chemical Analyses

Chemical measurements were performed on grab samples collected at each sampling location during each sampling event (critical period 2005, winter 2006, spring 2006, and critical period 2006). Grab samples for the analysis of chemical parameters were collected using an open-ended bailer. Protocols described in Section 2.1.2 of the LDEQ document entitled *Standard Operating Procedure for Water Sample Collection, Preservation, Documentation and Shipping* (LDEQ, 2004) were used for guidance. Following the LDEQ guidance explained in the *QAPP for the Evaluation of Aquatic Life Uses and Dissolved Oxygen Criteria in the Terrebonne and Barataria Basins* (LDEQ, 2005), instantaneous grab samples were collected between the hours of midnight (0000 hours) and noon (1200 hours) in an effort to collect data when DO concentrations are the lowest in the diurnal cycle. Samples were collected from mid-depth or 1 meter (whichever was less) and a replicate sample was collected for every 10 samples collected in the field. This was accomplished by collecting duplicate samples for all parameters at one of the 15 sites sampled during each sampling event. The location of the duplicate sample collection was different for each of the four sampling events.

In addition to water samples, sediment samples were collected using a petite ponar to provide physical habitat data (TOC and grain size). Samples were collected during daylight hours and shipped on ice to the EPA Region 6 Houston Laboratory via overnight courier. The only exception was for sediment samples which were kept on ice and shipped as soon as practical.

Analyses were conducted by the TCEQ laboratory for the chemical parameters listed in Table 3-2.

Some additional parameters were analyzed by the laboratory; however, these were not within the scope of the study. These results of these additional analyses are tabulated but not discussed in this report.

Table 3-2. List of Physical/Chemical Parameters for Laboratory Analysis, Methods, and Supporting Information

Parameter	EPA Analytical Method	Preservation	Maximum Holding Time	Detection Limits (mg/L)
Total phosphorus	EPA 365.4	H_2SO_4 to pH <2 Refrigerate at 4˚C	28 days	0.01
Ammonia	EPA 350.1	H_2SO_4 to pH <2 Refrigerate at 4˚C	28 days	0.01
Total Kjeldahl nitrogen (TKN)	EPA 351.2	H_2SO_4 to pH <2 Refrigerate at 4˚C	28 days	0.1
Nitrates	EPA 353.2	H_2SO_4 to pH <2 Refrigerate at 4˚C	48 hours	0.05
Nitrite	EPA 353.2	No chemical preservation; Refrigerate at 4˚C	48 hours	0.05
Total suspended solids (TSS)	EPA 160.2	Refrigerate at 4˚C	7 days	4
Biochemical oxygen demand (BOD)	EPA 405.1	Refrigerate at 4˚C	48 hours	2
Chlorophyll *a*	SM 10200H (spectrophotometric)	Refrigerate at 4˚C	48 hours	0.001
Sediment grain size	EPA 600/2-78-054	Refrigerate at 4˚C	28 days	NA
Sediment TOC	EPA 415.2	Refrigerate at 4˚C	28 days	0.05

3.2 Habitat Assessment and Benthic Macroinvertebrates

The habitat assessment was completed for each site using a Physical /Chemical Field sheet modified based upon the Florida Department of Environmental Protection (FDEP) Form FD9000-3, Stream/River Habitat Assessment Field Sheet FDEP Form FD 9000-5, and FD 9000-6.

Following the habitat assessment, benthic macroinvertebrates were sampled. Benthic macroinvertebrates were collected at Sites C-1 through C-10 during August 24 to August 28, 2005. Due to the occurrence of Hurricanes Katrina and Rita, sampling for sites C-11 through C-15 could not be accomplished during the critical period in 2005 and had to be postponed. Benthic macroinvertebrate sampling for sites C-11 through C-15, as well as re-sampling of sites C-1 through C-10, was conducted July 31 to August 9 during the critical period in 2006. The sampling procedures are described below.

A team of two individuals conducted the benthic macroinvertebrate community sampling at all reference locations. All sampling occurred within the 100-meter reach of the initial habitat assessments. Dip net samples for all locations were collected following the FDEP *Stream Condition Index Method* (FS7000, FDEP2004), while petite ponar samples were collected following EPA's *Estuarine and Coastal Marine Waters: Bioassessment and Biocriteria Technical*

Guidance (Bowman 2000) and modified EMAP protocols. Modifications to the ponar sampling were consistent at all reference locations and collection dates and involved the collection of three individual petite ponar samples that were then composited to represent the sediment as a habitat type to be identified separate from the dip-net samples. These three samples were collected from near shore, near "channel" and "channel", respectively. "Channel" is defined as the deepest portion of the waterbody within the 100 meter reach. This modification was made to encompass the various sediment characteristics (i.e. sand, organic debris, mud/muck, clay, etc.) for each reference location.

At each site, 20 sweeps with a standard D-Net were taken in proportion to the habitat types present (i.e., undercut banks, vegetative areas SAVs, inorganic substrate, roots/snags, oyster rubble/shell hash) within the 100 meter reach and not greater than approximately 20 times the wetted stream width of the water body. This was modified depending on the site and stream width. A 'sweep' consisted of an approximately 0.5-meter agitation of substrate resulting in approximately 2.5 m^2 of sampled habitat area. All sweeps from a site were composited and processed as a single sample. Environmental factors that may cause interference or bias of results were noted on field sheets during sampling events.

Collected samples were sieved in the field using a standard 500-micron sieve bucket to remove small debris and excess sediment. Extremely large debris were thoroughly washed into the sieve and discarded. In addition, 3 petite ponar grabs were collected at each site to include sediments as a habitat type. The three grabs were composited, as explained previously. Immediately following collection, samples were placed in labeled containers. Additional labels were placed inside all biological samples to identify the samples in the event the outer label was accidentally removed or obliterated. During the critical period of 2005, samples were immediately preserved in 10 percent Rose Bengal-stained formalin and delivered to the laboratory upon completion of the sampling event. During the critical period of 2006, samples were collected and preserved in 90 percent ethanol prior to delivery to the laboratory. Laboratory taxonomic evaluation of benthic macroinvertebrate samples were performed according to sorting and identification procedures in EPA document 841-B-99-002 (Barbour et al. 1999) and following laboratory SOPs. Upon receipt of the benthic samples at the laboratory, the samples were inventoried. During 2005, samples were washed and transferred from the 10 percent formalin solution to 70 percent isopropyl alcohol.

Benthic samples were sorted and separated into major phylogenetic categories. All organisms were removed with fine-tipped forceps or a pipette and placed in shell vials containing 70 percent isopropyl alcohol solutions. Samples were subsampled to 300 organisms per sample.

3.3 Fish

All fish sampling was conducted during July 31 to August 3 (Sites C-1 through C-10) and August 7 through August 9 (Sites C-11 through C-15) which was during the critical period for 2006. At Sites C-1 through C-10, electroshocking from a small boat was utilized. The 100-meters of stream identified in the habitat assessment were the focus of the fish collections although a greater distance was required based on the time selected for sampling effort. Fish samples were collected by electroshocking for 1800 seconds. Fish sampling at these sites was performed by Southeastern

Pond Management, Inc. under the direct supervision of Dr. Lance Fontenot of ARCADIS. Generally, fish were collected using a dip net and maintained in a live well until completion of sampling at a location. Some fish were visually identified and counted. All available and accessible habitat structure was sampled at each site. Fish were identified, counted, examined for disease and released. Fish were identified to species level. Three experienced biologists participated in fish identifications and any specimens with uncertain identification were collected and confirmed in the laboratory.

At Sites C-11 to C-15, all sampling was carried out on an outboard powered 19 ft workboat drawing approximately 1.5 ft of water. Locations for the survey were determined using Trimble NT300D 12 channel global positioning system (GPS) receivers. Data from the USCG differential GPS (DGPS) broadcast transmitter at English Turn, Louisiana (29° 52.7 degrees North Latitude, 89° 56.6 degrees West Longitude) were used to provide real time 2 differential correction (Type 9) of the GPS data. The differentially corrected position data accuracy is typically 1.0 meter or better for the NT300D DGPS.

Trawl samples were collected with a 16 ft otter trawl comparable to trawls used by the Louisiana Department of Wildlife & Fisheries, Marine Fisheries Division. The samples consisted of three-10 minute trawls. The contents of the net were placed in a washtub and the individuals identified, counted, examined for disease and released. Small individuals were handled the same as the larger individuals unless closer examination of the specimen was necessary for identification. Those individuals were preserved for identification, counting and measuring, if necessary. The sportfish collected at each sampling site were measured and released.

In addition to the trawl samples, two 50 foot gill nets with 1.5 inch stretch mesh were placed at locations in the bayou. The individuals collected by this method were handled in the same manner as the trawl samples.

Specimens were identified to genus and species in most cases. Lengths of the sportfish were taken and recorded. Due to the large number of anchovies collected in the trawls at location C-12, the number of specimens was approximated by weighing a known number of anchovies. The remainder of the anchovies in the sample was weighed and the number of specimens determined.

At site C-11, trawl number three was only pulled for eight minutes due to extremely shallow water at the east end of the bayou sampled. At sites C-14 and C-15 only one gill net was deployed due to damage to the second gill net rendering it nonfunctional.

In order to maintain quality control of the fish identifications, the field data sheets listing the identification, number and lengths (if required) were signed by the field personnel. Those specimens that were brought back and identified in the laboratory were discussed with knowledgeable fish personnel. These fish were then added to the Site data sheet, which was signed by the appropriate personnel.

4. Results

4.1 Overview

Section 4.1 presents an overview of the results of the four sampling events. Common trends and problems encountered are also discussed. In Section 4.2, the results are discussed for each site.

4.1.1 Physical and Hydrologic Measurements

Information obtained on physical stream parameters included: width (for waterbodies with a discernable channel, i.e., all except C-9), depth and flow (where measurable) and light penetration. Flow data from USGS gauging stations were not available for any of the reference stream sample sites. Therefore, flow measurements were made where possible (e.g., in wadeable streams with acceptable bottom conditions) according to standard operating procedures. In open waters or other locations where it was not feasible to measure flow accurately, qualitative observations were made. Depths shown are average channel depths unless otherwise indicated (i.e., open water). Most of the sample locations proved difficult for obtaining accurate flow measurements due to current velocities, stream depth, hazardous stream bottom conditions, tidal influences or weather conditions.

Hydrologic information including width, depth, flow and light penetration measurements collected or estimated for the sampling events are presented in Tables 4-1 through 4-4. Measurement of Secchi depth was inadvertently omitted at several locations, but this has no impact upon the results of the study since turbidity measurements were made. It should be noted that, since this project is not designed to provide flow data for use in modeling, accurate flow and discharge data are not critical to the interpretation of the project results. Estimated flows are reflective of surface conditions and are not reflective of flow variations that may occur throughout the water column.

4.1.2 Continuous Monitors

Four water quality field measurement deployments were completed at each of the sampling sites for a minimum 48-hour continuous monitoring period. The datasondes deployed in the project utilized state-of–the-practice instruments (YSI brand equipment) and were maintained and calibrated according to the manufacturer's recommendation. Field instrument calibration logs are provided in Appendix B. Calibrated DO readings before and after deployment are generally between 95 to 105%. However, excursion of acceptable calibration was observed in all sampling events, particularly in Events A and C. In Event A, the lowest calibrated reading was 50.9%, and the highest calibrated reading was 127%. In Event C, the lowest calibrated reading was 42.9%, and the highest calibrated reading was 114.5 %. Instrument or deployment errors were observed at several sites during summer 2005, winter 2006, and spring 2006, and the resulting abnormal data were not included in this analysis.

Table 4-1. Hydrological Parameters of Selected Reference Sites, August 2005

Site	Width (ft)	Water depth (ft)	Flow (ft/sec)	Discharge (cfs)	Light Penetration (m)
C-1	150	5.8	NM-slight surface flow observed.	NC	0.675
C-2*	311	5.25	0.112	184	NM
C-3	458	3.5	NM	NC	NM
C-4*	61	4.58	0.262	73.2	0.49
C-5	284	6.5	Moderate movement	NC	0.49
C-6	214	3.0	Moderate movement	NC	0.45
C-7	118	3.8	No flow	NC	NM
C-8	61	3.5	Slight movement	NC	0.6
C-9	Open water	2.75 (At station)	NM	NC	NM
C-10	90	4.5	Slow movement	NC	0.55
C-11	78	6.5	NM	NC	0.45
C-12	103	4.2	NM	NC	NM
C-13	164	3.25	0.5	267	0.485
C-14	238	3.5	0.5	417	0.275
C-15	164	4.5	0.5	369	NM

* Measured using flow meter

NM – Not Measured

NC – Not Calculated

Cfs – cubic feet per second

All values are estimated unless indicated otherwise

Table 4-2. Hydrological Parameters of Selected Reference Sites, January 2006

Site	Width (ft)	Water depth (ft)	Flow (ft/sec)	Discharge (cfs)	Light Penetration (m)
C-1	150	6.25	0.25	234	0.4
C-2	311	5.20	No flow	NC	0.125
C-3	458	3.0	NM	NC	NM
C-4	61	4.5	Very slow, to no flow	NC	0.2
C-5	284	5.5	0.017	26.6	0.25
C-6	214	3.3	No movement	NC	0.375
C-7	118	3.7	No flow, light chop	NC	0.13
C-8	61	2.2	0.033	4.4	NM
C-9	Open water	3 (At station)	Light chop	NC	0.125
C-10	90	4.0	No flow	NC	NM
C-11	78	6.0	NM	NC	NM
C-12	103	4.0	NM	NC	NM
C-13	164	3.1	No flow	NC	NM
C-14	238	3	NM	NC	NM
C-15	164	4.5	Light chop	NC	NM

* Measured using flow meter

NM – Not Measured

NC – Not Calculated

Cfs – cubic feet per second

All values are estimated unless indicated otherwise

Table 4-3. Hydrological Measurement Results of Reference Sites, April 2006

Site	Width(ft)	Water depth (ft)	Flow (ft/sec)	Discharge (cfs)	Light Penetration (m)
C-1	150	6.3	0.5	472.5	0.3
C-2	311	5.2	NM	NC	0.4
C-3	458	3.30	0.5	755	0.25
C-4	61	4.5	0.25	68.6	0.3
C-5	284	5	0.0055	7.81	0.25
C-6	214	3.2	0.083	56.8	0.45
C-7	118	4.0	NM	NC	0.40
C-8	61	2.7	0.01	1.6	0.24
C-9	Open water	3 (At Station)	NM	NC	0.40
C-10	90	5.2	No stream movement	NC	0.60
C-11	78	7.0	0.03	16.38	0.6
C-12	103	4.65	1.0	479	0.25
C-13	164	4.8	NM	NC	0.3
C-14	238	3.75	0.2	178	0.3
C-15	164	4.25	0.2	139.4	0.35

* Measured using flow meter

NM – Not Measured

NC – Not Calculated

Cfs – cubic feet per second

All values are estimated unless indicated otherwise

Table 4-4. Hydrological Measurement Results of Selected Reference Sites, August 2006

Site	Width (ft)	Water depth (ft)	Flow (ft/sec)	Discharge (cfs)	Light Penetration (m)
C-1	150	6.5	NM – No Flow	NC	0.30
C-2	311	5.35	NM – No Flow	NC	0.20
C-3	458	3.5	NM – No Flow	NC	0.25
C-4	61	4.5	NM – No Flow	NC	0.15
C-5	284	4.5	0.2	255.6	0.20
C-6	214	3.25	0.17	118.2	0.35
C-7	118	4.0	NM – No Flow	NC	0.45
C-8	61	2.5	NM – No Flow	NC	0.25
C-9	Open water	3 (At Station)	NM – No Flow	NC	0.20
C-10	90	4.75	NM – No Flow	NC	0.65
C-11	78	7.0	NM – No Flow	NC	0.30
C-12	103	4.5	NM – No Flow	NC	0.30
C-13	164	3.25	NM – No Flow	NC	0.25
C-14	238	3.5	NM – No Flow	NC	0.25
C-15	164	4.7	NM	NC	0.15

NM – Not Measured

NC – Not Calculated

Cfs – cubic feet per second

All values are estimated unless indicated otherwise

A summary of the unusual data from continuous monitors is presented below. Typically, data points recorded at the beginning of a run or at the end of a run appeared anomalous. This suggests deployment error in that the sonde was not stabilized during initial deployment or was not turned off quickly enough after sonde retrieval. These data points were omitted from further data analyses.

- Site C-1, Event C: Data from 4/23/2006 14:18:29 to 4/23/2006 15:03:30 (2 out of 280 data points omitted).

- Site, C-2 , Event A: Data appeared anomalous based on the larger than expected fluctuation of DO concentration. However, other parameters appear to be within normal limits and, therefore, all data are presented.

- Site C-4, Event C: Data from 4/17/2006 13:12:32 to 4/17/2006 13:15:20 (2 out of 196 data points omitted).

- Site C-5, Event A: Data from 8/19/2005 11:45:40 to 8/19/2005 13:30:40 (8 out of 211 data points omitted); Event C: Data from 4/23/2006 12:10:30 to 4/23/2006 14:55:30 (12 out of 288 data points omitted).

- Site C-6, Event A: Data at 8/18/2005 14:00:28 (1 out of 195 data points omitted); Event C: Data from 4/23/2006 12:40:27 to 4/23/2006 15:10:28 (11 out of 287 data points omitted).

- Site C-9, Event A: Data from 8/15/2005 9:00:28 to 8/15/2005 10:15:27 (6 out of 182 data points omitted). Also, data from 8/17/2005 6:30:26 to 8/17/2005 13:00:25 (26 data points) were omitted because the probe was damaged by an apparent animal bite.

- Site C-10, Event A: Data at 8/16/2005 10:23:03 (1 out of 195 data points omitted); Event C: Data from 4/23/2006 10:10:30 to 4/23/2006 10:55:30 (4 out of 287 data points omitted).

- Site C-11, Event A: Data from 8/26/2005 11:45:40 to 8/26/2005 16:30:40 (20 out of 288 data points omitted).

- Site C-12, Event A (all data). This instrument malfunctioned during the event.

- Site C-14, Event B: Data from 1/26/2006 9:15:00 to 1/26/2006 11:30:30 (8 out of 282 data points omitted); Event C: Data at 4/27/2006 12:00:28 (1 out of 205 data points omitted).

- Site C-15, Event A: Data at 8/26/2005 17:30:08 (1 out of 214 data points omitted); Event C: Data at 4/27/2006 12:15:40 (1 out of 204 data points omitted).

Water quality field measurements are presented in four tables (Tables 4-5 through 4-8, one table per event) as the average, minimum and maximum values for DO, pH, temperature, conductivity, salinity, and turbidity. Appendix C contains graphs of DO versus time for each sampling event, while Appendix D contains graphs of DO, temperature, and pH versus time for each sampling event. Raw water quality measurement data are also included on a CD in Appendix E provided in Excel files on CD. In these appendices, the data for each sampling event are assembled in groups designated by letters, with “A” indicating the Summer 2005 event, “B” indicating the Winter 2006 event, “C” indicating the Spring 2006 event, and “D” indicating the Summer 2006 event.

Table 4-5. Summary of Average, Maximum, and Minimum Values for DO, pH, Temperature, Specific Conductivity, Salinity, and Turbidity, Summer 2005

Location	DO (mg/L)			pH		temperature (°C)			sp. Cond. (uS/cm)			salinity (ppt)			Turbidity (NTU)		
	Min	Max	Average	Min	Max	Min	Max	Average	Min	Max	Average	Min	Max	Average	Min	Max	Average
C-1	2.43	11.89	6.02	7.55	8.54	30.00	32.81	30.75	429	447	438	0.20	0.21	0.21	21.7	71.4	36.8
C-2	0.13	17.94	6.66	7.12	8.40	29.87	34.02	31.72	424	434	431	0.20	0.21	0.20	29.9	104.4	60.6
C-3	1.96	6.91	4.19	7.72	8.51	30.39	34.37	32.07	344	351	349	0.16	0.17	0.16	11.4	82.2	28.9
C-4	1.56	14.26	4.40	7.09	9.14	29.78	35.08	32.09	22	353	340	0.17	0.17	0.16	44.6	116.9	69.6
C-5	2.90	5.98	4.40	7.14	7.87	30.38	32.24	31.38	425	444	436	0.20	0.21	0.21	95.8	174.1	121.7
C-6	1.88	9.34	4.85	7.09	8.12	30.69	34.87	32.14	323	418	369	0.15	0.20	0.17	12.8	67.8	29.9
C-7	1.01	7.92	3.78	7.31	9.19	28.89	35.53	31.00	241	272	255	0.11	0.13	0.12	16.7	1122.9	56.7
C-8	0.76	7.09	4.37	6.57	8.58	26.49	32.66	29.24	155	211	170	0.07	0.10	0.08	13.6	1603.5	35.4
C-9	2.54	10.72	6.06	8.71	9.53	30.88	36.32	33.40	349	373	363	0.16	0.18	0.17	17.5	77.0	28.1
C-10	4.90	12.42	8.71	7.29	7.99	29.30	32.95	30.59	259	302	277	0.12	0.14	0.13	12.5	31.7	17.9
C-11	4.44	10.08	7.79	7.45	7.98	29.56	32.76	30.95	20238	25745	23740	11.98	15.60	14.27	-3.3	41.8	8.5
C-12	NA	NA	NA	7.19	7.82	28.95	34.62	30.60	24504	28000	27425	14.77	17.11	16.72	-13.7	27.2	-3.6
C-13	3.04	11.37	7.24	7.05	7.91	29.54	34.30	31.44	20916	27153	23761	12.42	16.54	14.28	-1.6	23.3	8.6
C-14	5.92	10.64	8.59	7.44	8.06	29.95	33.26	31.38	15853	19785	17858	9.17	11.70	10.45	-84.5	-14.7	-79.5
C-15	2.32	19.27	11.88	7.30	7.97	29.95	32.98	31.60	17163	22627	19795	10.01	13.56	11.69	4.2	166.0	31.5

*negative values may indicate instrumentation problems (out of calibration range).

Table 4-6. Summary of Average, Maximum, and Minimum Values for DO, pH, Temperature, Specific Conductivity, Salinity, and Turbidity, Winter 2006

Location	DO (mg/L)			pH		temperature (°C)			sp. Cond. (uS/cm)			salinity (ppt)			Turbidity (NTU)		
	Min	Max	Average	Min	Max	Min	Max	Average	Min	Max	Average	Min	Max	Average	Min	Max	Average
C-1	6.76	9.29	7.72	7.72	8.13	12.92	14.54	13.75	363	389	374	0.17	0.19	0.18	22.2	47.1	32.2
C-2	8.27	9.69	8.96	7.62	7.78	7.70	14.60	13.82	227	303	256	0.11	0.15	0.12	76.1	147.2	106.7
C-3	6.80	9.49	8.01	7.79	8.38	11.25	16.11	13.91	304	331	315	0.15	0.16	0.15	24.2	96.7	42.8
C-4	7.12	9.76	8.18	7.82	8.48	11.45	14.31	13.35	371	397	380	0.18	0.19	0.18	23.8	57.0	35.6
C-5	8.59	10.98	9.89	7.75	8.19	10.89	12.93	12.24	402	433	418	0.19	0.21	0.20	30.0	78.4	43.2
C-6	4.18	9.01	5.92	7.26	7.75	12.48	15.25	14.24	360	389	375	0.17	0.19	0.18	21.7	453.4	37.4
C-7	7.86	13.26	10.15	7.41	8.62	9.80	16.14	12.86	461	529	486	0.22	0.26	0.24	13.7	117.1	39.3
C-8	2.30	6.01	3.91	6.69	7.03	10.67	15.37	12.73	380	463	398	0.18	0.22	0.19	4.2	34.3	8.6
C-9	8.78	10.52	9.79	7.93	8.44	11.95	15.53	13.53	432	523	454	0.21	0.25	0.22	17.3	410.0	156.8
C-10	5.18	9.82	7.42	6.97	8.30	11.72	15.59	13.94	1426	2169	1717	0.72	1.12	0.88	16.8	76.2	30.9
C-11	7.32	10.41	8.92	7.80	8.05	11.69	19.14	15.55	19160	33727	30677	11.43	21.20	19.10	3.3	164.9	27.3
C-12	5.90	8.77	7.40	7.85	8.10	11.10	19.00	15.21	33005	36730	35095	20.67	23.29	22.13	8.4	240.2	20.7
C-13	5.69	9.22	7.33	7.57	8.04	13.99	21.18	17.68	16681	23495	20318	9.83	14.26	12.18	6.0	52.7	16.4
C-14	7.64	12.22	9.48	7.76	8.37	11.61	21.74	16.80	9705	16933	14188	5.49	9.98	8.26	9.1	161.5	22.1
C-15	7.23	14.60	8.77	6.95	7.67	10.39	21.43	16.45	5090	15958	15159	2.75	11.88	8.88	8.1	151.9	34.9

Table 4-7. Summary of Average, Maximum, and Minimum Values for DO, pH, Temperature, Specific Conductivity, Salinity, and Turbidity, Spring 2006

Location	DO (mg/L)			pH		temperature (°C)			sp. Cond. (uS/cm)			salinity (ppt)			Turbidity (NTU)		
	Min	Max	Average	Min	Max	Min	Max	Average	Min	Max	Average	Min	Max	Average	Min	Max	Average
C-1	3.58	6.89	4.50	7.60	8.10	24.65	27.18	25.20	484	538	514	0.23	0.26	0.25	16.9	67.4	29.9
C-2	5.07	10.02	6.99	7.46	8.22	25.83	29.47	27.12	405	419	412	0.19	0.20	0.20	22.2	33.6	26.4
C-3	3.56	10.45	6.98	7.68	8.63	26.48	31.82	29.08	401	411	406	0.19	0.19	0.19	18.6	48.5	28.5
C-4	4.88	11.74	7.72	7.54	8.73	24.28	27.96	26.03	395	419	406	0.19	0.20	0.19	21.4	292.9	36.8
C-5	6.82	12.46	8.71	7.76	8.64	24.76	27.78	25.84	325	345	335	0.15	0.16	0.16	19.3	1063.6	43.8
C-6	3.11	12.91	6.35	7.02	8.27	26.90	30.43	28.21	354	380	369	0.17	0.18	0.17	5.9	1917.9	25.3
C-7	4.77	12.84	7.66	7.33	8.62	26.05	29.84	27.69	434	453	440	0.21	0.22	0.21	13.7	32.8	20.7
C-8	1.40	8.28	3.96	7.16	8.21	25.09	29.59	26.99	376	401	385	0.18	0.19	0.18	9.1	53.8	25.6
C-9	5.20	9.33	7.04	7.61	8.36	25.82	30.79	28.59	431	455	442	0.21	0.22	0.21	19.9	119.2	42.2
C-10	3.41	8.67	6.16	7.14	7.80	24.95	29.31	27.15	499	640	554	0.24	0.31	0.27	77.6	112.3	85.8
C-11	5.70	7.50	6.67	7.50	7.78	22.42	29.62	26.78	40111	47362	45346	25.63	30.76	29.31	10.3	497.5	44.3
C-12	5.90	8.46	7.19	7.17	7.67	22.91	31.19	26.69	39929	50016	47435	25.47	32.58	30.83	11.8	152.1	37.3
C-13	4.12	9.05	6.19	7.22	7.86	22.22	30.22	26.85	19549	44059	35770	11.65	28.39	22.56	12.1	146.6	26.1
C-14	5.76	8.43	6.70	7.05	7.72	21.69	29.98	26.09	22406	34222	29833	13.52	21.44	18.45	-16.2	153.8	5.3
C-15	4.04	9.39	6.46	7.27	7.99	22.68	30.25	26.60	4168	39729	20816	2.21	25.29	12.69	28.8	92.5	45.7

Table 4-8. Summary of Average, Maximum, and Minimum Values for DO, pH, Temperature, Specific Conductivity, Salinity, and Turbidity, Summer 2006

Location	DO (mg/L)			pH		temperature (°C)			sp. Cond. (uS/cm)			salinity (ppt)			Turbidity (NTU)		
	Min	Max	Average	Min	Max	Min	Max	Average	Min	Max	Average	Min	Max	Average	Min	Max	Average
C-1	2.82	10.35	5.70	7.91	8.77	29.97	32.58	30.83	435	509	487	0.21	0.24	0.23	10.9	42.4	20.8
C-2	1.46	6.94	3.32	7.34	8.00	30.28	33.50	31.25	363	406	391	0.17	0.19	0.18	24.7	48.2	33.6
C-3	2.69	7.53	4.60	7.04	8.06	29.68	33.48	31.18	373	386	380	0.18	0.18	0.18	16.6	117.9	32.5
C-4	1.36	9.78	3.14	7.45	8.56	29.05	35.20	30.79	378	429	405	0.18	0.20	0.19	23.3	97.3	36.0
C-5	2.40	7.32	3.57	7.20	7.91	28.48	31.88	30.05	190	369	289	0.09	0.17	0.14	19.4	65.3	38.1
C-6	1.08	12.79	4.15	7.19	8.47	28.75	33.62	30.48	323	420	352	0.15	0.20	0.16	2.4	66.6	10.1
C-7	0.92	11.96	3.95	7.06	9.12	28.41	35.90	31.05	334	359	349	0.16	0.17	0.16	4.2	26.7	11.8
C-8	1.59	14.13	5.01	7.28	9.17	28.55	33.95	30.26	360	386	379	0.17	0.18	0.18	12.2	299.3	28.6
C-9	2.56	12.60	6.33	7.65	9.09	30.05	35.27	32.09	399	424	409	0.19	0.20	0.19	19.7	2246.0	50.1
C-10	0.84	6.86	3.18	7.13	8.34	28.62	31.78	29.89	518	583	545	0.25	0.28	0.26	2.4	12.1	4.8
C-11	2.99	7.66	5.27	6.93	7.46	30.82	34.51	32.46	32579	35958	34594	20.14	22.54	21.56	7.8	48.8	16.9
C-12	3.01	7.90	5.46	6.94	7.76	29.65	35.35	31.83	36658	41111	39683	22.97	26.13	25.12	12.6	54.3	26.8
C-13	1.61	8.28	4.79	7.19	7.83	31.09	35.78	32.85	19978	30003	25013	11.79	18.44	15.08	12.6	38.2	21.3
C-14	3.10	9.34	6.83	7.43	8.16	30.25	35.41	32.32	14147	20369	18305	8.09	12.08	10.73	12.8	38.1	21.6
C-15	3.43	7.76	5.51	7.12	7.92	30.46	33.49	31.88	7725	24238	16697	4.22	14.60	9.75	18.8	218.8	39.6

4.1.2.1 Dissolved Oxygen

Hourly DO readings from each datasonde were averaged to produce a 48-hour average DO value for each site at each sampling event. In addition, the minimum DO measured during the entire 48-hour sampling period was noted. These values are compared to the LDEQ water quality standards (LDEQ, 2006), which, for the Terrebonne Basin, are DO of 5 mg/L for segments that include sites C-1 through C-10 and a DO of 4 mg/L for those segments that include sites C-11 through C-15.

Event A, Critical Period 2005:

Field measurements from the first sampling event that did not meet the LDEQ water quality standard are listed below.

- DO minimum at C-1, C-2, C-3, C-4, C-5, C-6, C-7, C-8, and C-9
- DO minimum at C-13, and C-15

Data from C-12 were anomalous and indicative of a sonde malfunction. Thus, data from C-12 were not evaluated. The most significant excursions from the water quality standard were DO readings at C-4. DO was consistently below 5 mg/L for about 18 hours. While DO values recorded at C-10 were below 5 mg/L at two sampling times, LDEQ water quality standards allow naturally occurring variation below the criterion for short periods.

Event B, Winter 2006:

Field measurements from the second sampling event that did not meet the LDEQ water quality standard are listed below.

- DO minimum at C-6 and C-8

At site C-8, the minimum DO reading was 2.30 mg/L. DO was below 5 mg/L most of the time for about 46 hours starting from 16:55 pm to 14:55 pm two days later.

Event C, Spring 2006:

Field measurements from the third sampling event that did not meet the LDEQ water quality standard are listed below.

- DO minimum at C-1, C-3, C-4, C-6, C-7, C-8, and C-10

While DO values recorded at C-3 and C-7 were below 5 mg/L at several sampling times, LDEQ water quality standards allow naturally occurring variation below the criterion for short periods.

Event D, Critical Period 2006:

Field measurements from the fourth sampling event that did not meet the LDEQ water quality standard are listed below.

- DO minimum at C-1, C-2, C-3, C-4, C-5, C-6, C-7, C-8, C-9, and C-10
- DO minimum at C-11, C-12, C-13, C-14, and C-15

DO values recorded at C-14 were below 4 mg/L for about 1.5 hrs from 6:15 am to 7:45 am at the end of the monitoring period. The lowest DO value was 3.1 mg/L at this site.

The most significant excursions from the water quality standard were DO readings at C-2, C-4, C-5, C-6, C-7, and C-10. At site C-2, the average DO value was 3.3 mg/L, and only 6.4 percent of the continuous DO readings were above 5 mg/L. For C-4, the minimum DO value was 1.36 mg/L, and the average was 3.1 mg/L with a relatively large standard deviation of 1.7 mg/L. At site C-5, the 48 hr average DO concentration was 3.6 mg/L, and DO values were below 5 mg/L for 94.8 percent of the sampling time. Average DO concentrations were 4.2 mg/L at site C-6, 3.95 mg/L at site C-7, and 3.2 mg/L at site C-10.

4.1.2.2 pH

pH values were evaluated by comparison with the LDEQ water quality standard: the pH shall fall within the range of 6.0 to 9.0 unless natural conditions exceed this range or where otherwise specified in the table (LAC 33:IX.1123) of LDEQ water quality criteria. The LDEQ water quality standards for the Terrebonne Basin are pH of 6 to 8.5 for segments that include sites C-1 through C-10 and a pH of 6.5 to 9 for those segments that include sites C-11 through C-15.

Event A, Critical Period 2005:

Field measurements from the first sampling event that did not meet the LDEQ water quality standard are listed below.

- pH maximum at C-4, C-7, and C-9

At site C-4 and C-7, pH was temporarily higher than 8.5, and the maximum value was approximately 9.2. The most significant excursions from the water quality standard were pH readings from site C-9, where pH values were over 8.5 during more than 50 percent of sampling times.

Event B, Winter 2006:

Field measurements from the second sampling event that did not meet the LDEQ water quality standard are listed below.

- pH maximum at C-7

At site C-7, the maximum pH value was 8.62.

Event C, Spring 2006:

Field measurements from the third sampling event that did not meet the LDEQ water quality standard are listed below.

- pH maximum at C-3, C-4, C-5, and C-7

At sites C-3, C-4, C-5, and C-7, pH was temporarily higher than 8.5, with a maximum value of 8.73.

Event D, Critical Period 2006:

Field measurements from the fourth sampling event that did not meet the LDEQ water quality standard are listed below.

- pH maximum at C-1, C-7, C-8, and C-9

At sites C-1, C-7, C-8, and C-9, pH was temporarily higher than 8.5, with a maximum value of approximately 9.2.

4.1.2.3 Temperature

The LDEQ water quality standards for the Terrebonne Basin are a maximum value of 32 ºC for segments that include sites C-1 through C-10, and a maximum value of 35 ºC for those segments that include sites C-11 through C-15.

Event A, Critical Period 2005:

Field measurements from the first sampling event that did not meet the LDEQ water quality standard are listed below.

- Maximum temperature at C-1, C-2, C-3, C-4, C-6, C-7, C-8, C-9 and C-10.

Event B, Winter 2006:

All field measurements from the second sampling event met the LDEQ water quality standard.

Event C, Spring 2006:

All field measurements from the third sampling event met the LDEQ water quality standard.

Event D, Critical Period 2006:

Field measurements from the fourth sampling event that did not meet the LDEQ water quality standard are listed below.

- Maximum temperature at C-1, C-2, C-3, C-4, C-6, C-7, C-8, and C-9.

- Maximum temperature at C-12, C-13, and C-14.

4.1.2.4 Specific Conductivity and Salinity

The specific conductivity and salinity at freshwater sites C-1 to C-5 were very similar to the mixed sites C-6 to C-10 (specific conductivity typically averaging < 500 $\mu S/cm^2$ and salinity typically averaging <0.25 ppt). No distinct seasonal trends were observed with the exception of an increase in salinity and specific conductivity during winter 2006 at sites C-7, C-8, C-9, and C-10. Although the observed salinity of sites C-6 through C-10 was similar to the freshwater sites, these sites were classified as mixed based upon the vegetation types present and the tidal influence. Seasonal fluctuations in salinity were observed at saline sites C-11 through C-15 with highest salinity observed in spring 2006.

4.1.2.5 Turbidity

Fifty NTU has been given as a guideline for estuarine lakes, bayous, canals and rivers in certain Louisiana basins (LDEQ 2006). Using 50 NTU as a guideline, sporadic exceedances occurred at all sites, but, overall, turbidity was low. During summer 2005, negative values were recorded at sites C-11 through C-14. These negative values may indicate instrumentation problems (out of calibration range). Turbidity values for these sites were within expected values for all other sampling events.

4.1.3 Chemical Parameters

Results of analysis of water grab samples and sediment TOC and grain size analysis from the four sampling events on the waterbodies in the Terrebonne Basin are presented in Tables 4-9 to 4-15. As noted previously and reflected on the sample designations on the tables, the four sampling events have been designated as follows: A – Summer 2005; B – Winter 2006; C – Spring 2006; and D – Summer 2006. The full laboratory reports are presented in Appendix F, along with laboratory QC data. Because of broken sample containers during summer 2005, sediment data are only available from sites C-1, C-2, C-7, C-9, and C-10. However, the locations with missing sediment data were sampled during spring 2006.

Table 4-9. Surface Water Analytical Data Summary, Summer 2005

Water Quality Parameters (mg/L)	C-1A 8/15/2005	C-2A 8/16/2005	C-3A 8/16/2005	C-4A 8/16/2005	C-5A 8/17/2005	C-6A 8/16/2005	C-7A 8/15/2005	DUP-1A (C-7A) 8/15/2005
Ammonia as N	0.14	0.14	<0.05	0.5	0.1	0.06	0.16	0.15
Biochemical Oxygen Demand, 5 day (BOD5)	4	3	6	<3	<3	3	4	4
Chemical Oxygen Demand (COD)	NA	NA	NA	NA	NA	NA	NA	NA
Chlorophyll-A	0.0251	0.0641	0.0814	<0.010	0.0205	0.0358	0.0594	0.0534
Nitrate-N	<0.02	<0.02	<0.02	0.13	0.19	<0.02	0.02	0.02
Nitrite-N	0.08	0.03	0.02	0.05	0.06	0.02	0.03	0.03
Pheophytin-A	0.0198	0.0144	0.0279	<0.005	0.00756	0.00534	0.0224	0.0204
Phosphorus, Total	0.22	0.32	0.27	0.24	0.21	0.44	0.46	0.48
Total Kjeldahl Nitrogen (TKN)	1.15	1.37	1.38	1.2	1	0.89	1.56	1.48
Total Organic Carbon (TOC)	NA	NA	NA	NA	NA	NA	NA	NA
Total Suspended Solids (TSS)	26	48	46	20	48	18	14	14
Volatile Suspended Solids (VSS)	5	8	12	3	6	4	7	7

< Less than the reporting limit

NA Not analyzed

Table 4-9 continued on next page

Table 4-9. Surface Water Analytical Data Summary, Summer 2005 (continued)

Water Quality Parameters (mg/L)	C-8A 8/15/2005	C-9A 8/15/2005	C-10A 8/16/2005	C-11A 8/23/2005	C-12A 8/23/2005	C-13A 8/24/2005	C-14A 8/24/2005	C-15A 8/24/2005
Ammonia as N	0.17	0.1	0.08	<0.05	<0.05	0.11	<0.05	<0.05
Biochemical Oxygen Demand, 5 day (BOD5)	4	4	3	NA	NA	3	5	4
Chemical Oxygen Demand (COD)	NA	NA	NA	340	650	NA	NA	NA
Chlorophyll-A	0.0708	0.0523	0.0487	0.0267	0.0222	0.0151	0.0312	0.0267
Nitrate-N	0.03	0.03	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Nitrite-N	0.03	0.02	0.03	<0.02	0.02	<0.02	<0.02	0.03
Pheophytin-A	0.0241	0.0131	0.0158	0.00757	0.0108	0.00917	0.0112	0.0175
Phosphorus, Total	0.23	0.2	0.14	0.15	0.15	0.17	0.15	0.18
Total Kjeldahl Nitrogen (TKN)	1.51	1.26	0.96	1.84	2.11	1.66	1.7	1.84
Total Organic Carbon (TOC)	NA	NA	NA	6	5	NA	NA	NA
Total Suspended Solids (TSS)	22	15	8	18	44	20	24	44
Volatile Suspended Solids (VSS)	8	6	4	7	11	5	7	6

< Less than the reporting limit

NA Not analyzed

Table 4-10. Sediment Analytical Data Summary, Summer 2005

Conventional Parameters	C-1A	DUP-C-2A	C-7A	C-9A	C-10A
	8/27/2005	8/27/2005	8/25/2005	8/25/2005	8/24/2005
Total Organic Carbon (TOC) (mg/kg)	13,300	23,900	68,000	10,900	400,000
Percent Total Solids (%)	58.19	50.18	19.7	53.49	9.3
Sediment Particles, Clay (%)	76.7	20.01	NA	8.13	NA
Sediment Particles, Gravel (%)	<0.01	<0.01	NA	<0.01	NA
Sediment Particles, Sand (%)	8.37	67.59	NA	71.53	NA
Sediment Particles, Silt (%)	14.93	12.41	NA	20.33	NA

< Less than the reporting limit

NA Not analyzed

Table 4-11. Surface Water Analytical Data Summary, Winter 2006

Water Quality Parameters (mg/L)	C-1B	C-2B	C-3B	C-4B	C-5B	C-6B	C-7B
	1/16/2006	1/16/2006	1/16/2006	1/16/2006	1/16/2006	1/16/2006	1/17/2006
Ammonia as N	0.18	0.12	0.14	<0.05	0.08	0.09	<0.05
Biochemical Oxygen Demand, 5 day (BOD5)	<3	<3	3	3	<3	<3	6
Chemical Oxygen Demand (COD)	NA	NA	NA	NA	NA	NA	NA
Chlorophyll-A	0.0196	0.02	0.0374	0.0374	0.0107	0.0294	0.107
Nitrate-N	0.27	0.28	0.32	0.38	1.25	0.79	0.03
Nitrite-N	0.07	0.07	0.04	0.03	0.05	0.03	0.04
Pheophytin-A	0.0159	0.0118	0.0308	0.0164	0.00801	0.0161	0.0558
Phosphorus, Total	0.17	0.26	0.2	0.17	0.23	0.23	0.33
Total Kjeldahl Nitrogen (TKN)	0.88	0.95	1.19	0.99	0.74	0.79	1.8
Total Organic Carbon (TOC)	NA	NA	NA	NA	NA	NA	NA
Total Suspended Solids (TSS)	33	83	67	40	70	60	126
Volatile Suspended Solids (VSS)	6	10	13	6	7	12	29

< Less than the reporting limit

NA Not analyzed

Table 4-11 continued on next page

Table 4-11. Surface Water Analytical Data Summary, Winter 2006 (continued)

Water Quality Parameters (mg/L)	C-8B	C-9B	DUP-01 (C-9B)	C-10B	C-11B	C-12B	C-13B	C-14B	C-15B
	1/17/2006	1/17/2006	1/17/2006	1/17/2006	1/24/2006	1/24/2006	1/23/2006	1/23/2006	1/23/2006
Ammonia as N	0.46	0.07	<0.05	0.06	0.18	0.09	0.31	0.06	0.4
Biochemical Oxygen Demand, 5 day (BOD5)	5	5	5	4	<3	<3	<3	4	3
Chemical Oxygen Demand (COD)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chlorophyll-A	0.036	0.0534	0.0534	0.0694	0.0195	0.0139	0.0153	0.0192	0.015
Nitrate-N	0.09	0.02	0.02	0.16	0.24	0.02	0.13	<0.02	0.12
Nitrite-N	0.03	0.03	0.03	0.02	0.03	<0.02	0.03	<0.02	0.04
Pheophytin-A	0.0191	0.0438	0.0457	0.0222	<0.005	0.0078	<0.005	0.00918	0.0078
Phosphorus, Total	0.22	0.34	0.34	0.17	0.17	0.11	0.08	0.11	0.12
Total Kjeldahl Nitrogen (TKN)	1.35	1.6	1.45	1.2	2.63	0.9	NA	1.41	1.4
Total Organic Carbon (TOC)	NA	NA	NA	NA	NA	NA	3	6	4
Total Suspended Solids (TSS)	60	141	117	38	115	33	26	30	48
Volatile Suspended Solids (VSS)	13	28	24	12	24	7	6	7	10

< Less than the reporting limit

NA Not analyzed

Table 4-12. Surface Water Analytical Data Summary, Spring 2006

Water Quality Parameters (mg/L)	C-1C	C-2C	C-3C	C-4C	C-5C	C-6C	C-7C
	4/17/2006	4/17/2006	4/17/2006	4/17/2006	4/17/2006	4/17/2006	4/18/2006
Ammonia as N	0.16	<0.05	<0.05	0.06	<0.05	0.09	0.05
Biochemical Oxygen Demand, 5 day (BOD5)	<3	5	5	6	<3	4	5
Chlorophyll-A	<0.010	0.0154	0.0192	0.0234	<0.010	0.0160	0.0409
Nitrate-N	0.25	<0.02	<0.02	0.42	1.00	<0.02	<0.02
Nitrite-N	0.03	<0.02	0.03	0.03	0.03	<0.02	<0.02
Pheophytin-A	0.0105	0.0248	0.0279	0.0336	0.0081	0.0232	0.0245
Phosphorus, Total	0.18	0.19	0.17	0.21	0.17	0.47	0.16
Total Kjeldahl Nitrogen (TKN)	0.95	1.21	1.23	1.38	0.78	1.48	1.45
Total Suspended Solids (TSS)	30	34	42	37	35	29	33
Volatile Suspended Solids (VSS)	5	6	9	8	4	8	11

< Less than the reporting limit
NA Not analyzed

Table 4-12 continued on next page

Table 4-12. Surface Water Analytical Data Summary, Spring 2006 (continued)

Water Quality Parameters (mg/L)	C-8C	C-9C	DUP-01 (C-1C)	C-10C	C-11C	C-12C	C-13C	C-14C	C-15C
	4/18/2006	4/18/2006	4/17/2006	4/18/2006	4/24/2006	4/24/2006	4/24/2006	4/25/2006	4/25/2006
Ammonia as N	0.09	<0.05	0.17	0.10	0.06	0.09	0.09	0.06	0.10
Biochemical Oxygen Demand, 5 day (BOD5)	5	3	<3	<3	<3	3	4	<3	4
Chlorophyll-A	0.0303	0.0187	<0.010	<0.010	<0.010	<0.010	0.0139	0.0107	0.0246
Nitrate-N	<0.02	<0.02	0.27	0.17	<0.02	<0.02	<0.02	<0.02	<0.02
Nitrite-N	0.02	<0.02	0.03	<0.02	<0.02	0.02	<0.02	0.02	<0.02
Pheophytin-A	0.0358	0.0218	0.0122	0.0228	0.0114	0.0204	0.0235	0.0220	0.0151
Phosphorus, Total	0.28	0.12	0.17	0.11	0.09	0.15	0.18	0.19	0.16
Total Kjeldahl Nitrogen (TKN)	1.69	1.10	0.98	1.02	1.47	1.87	1.88	2.03	1.51
Total Suspended Solids (TSS)	36	30	32	16	48	94	66	187	35
Volatile Suspended Solids (VSS)	12	9	6	5	13	24	15	33	8

< Less than the reporting limit

NA Not analyzed

Table 4-13. Sediment Analytical Data Summary, Spring 2006

Conventional Parameters	C-1C	C-2C	C-3C	C-4C	C-5C	C-6C	C-7C	C-8C	C-9C	DUP-01 (C-1C)	C-10C
	4/17/2006	4/17/2006	4/17/2006	4/17/2006	4/17/2006	4/17/2006	4/18/2006	4/18/2006	4/18/2006	4/17/2006	4/18/2006
Total Organic Carbon (TOC) (mg/kg)	6,860	14,700	72,600	38,300	23,600	53,500	96,600	65,700	25,000	13,400	283,000
Percent Total Solids (%)	54.05	59.90	21.97	40.42	34.65	42.27	22.21	24.55	41.43	53.90	6.92
Sediment Particles, Clay (%)	63.70	11.05	73.76	29.55	68.60	48.92	54.59	56.22	71.81	80.83	NA
Sediment Particles, Gravel (%)	0	0	0	0	0	0	0	0	0	0	NA
Sediment Particles, Sand (%)	30.09	58.10	3.98	34.11	-3.47	26.00	21.66	5.68	7.73	12.83	NA
Sediment Particles, Silt (%)	6.21	30.86	22.26	36.34	34.87	25.08	23.75	38.11	20.46	6.34	NA

< Less than the reporting limit

NA Not analyzed

Table 4-14. Surface Water Analytical Data Summary, Summer 2006

Water Quality Parameters (mg/L)	C-1D	C-2D	C-3D	C-4D	C-5D	C-6D	C-7D
	8/8/2006	8/8/2006	8/8/2006	8/8/2006	8/9/2006	8/8/2006	8/7/2006
Ammonia as N	0.1	0.08	<0.05	0.12	0.1	0.12	0.09
Biochemical Oxygen Demand, 5 day (BOD5)	<3	<3	5	<3	<3	<3	4
Chlorophyll-A	0.0267	0.0214	0.079	<0.010	0.016	0.0246	0.0315
Nitrate-N	<0.02	<0.02	<0.02	0.03	0.35	0.09	0.03
Nitrite-N	0.06	0.02	<0.02	0.04	0.03	0.02	<0.02
Pheophytin-A	0.00993	0.00705	0.0122	<0.005	<0.005	0.0151	0.0156
Phosphorus, Total	0.2	0.33	0.36	0.29	0.25	0.49	0.39
Total Kjeldahl Nitrogen (TKN)	0.95	0.86	1.14	0.79	0.78	0.91	1.43
Total Suspended Solids (TSS)	23	34	29	25	48	30	20
Volatile Suspended Solids (VSS)	5	5	8	4	8	6	9

< Less than the reporting limit

NA Not analyzed

Table 4-14 continued on next page

Table 4-14. Surface Water Analytical Data Summary, Summer 2006 (continued)

Water Quality Parameters (mg/L)	C-8D	C-9D	DUP-01 (C-10D)	C-10D	C-11D	C-12D	C-13D	C-14D	C-15D
	8/7/2006	8/7/2006	8/7/2006	8/7/2006	7/31/2006	7/31/2006	7/31/2006	7/31/2006	7/31/2006
Ammonia as N	0.21	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Biochemical Oxygen Demand, 5 day (BOD5)	6	6	<3	<3	4	3	3	4	4
Chlorophyll-A	0.0801	0.0854	0.0347	0.032	0.0235	0.016	0.0267	0.0267	0.0534
Nitrate-N	<0.02	<0.02	0.05	0.04	<0.02	<0.02	<0.02	0.04	<0.02
Nitrite-N	0.03	0.03	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02	<0.02
Pheophytin-A	0.0302	0.0211	0.0172	0.0158	0.0124	0.0079	0.00881	<0.005	0.0148
Phosphorus, Total	0.92	0.36	0.14	0.15	0.15	0.13	0.19	0.13	0.22
Total Kjeldahl Nitrogen (TKN)	2.4	1.76	0.9	0.86	1.95	1.77	1.7	1.57	1.8
Total Suspended Solids (TSS)	78	56	11	11	36	83	54	44	70
Volatile Suspended Solids (VSS)	20	16	5	5	15	31	19	17	22

< Less than the reporting limit

NA Not analyzed

Table 4-15. Sediment Analytical Data Summary, Summer 2006

Conventional Parameters	C-11A/B	C-12A/B	C-12 Rep	C-13A/B	C-14A/B	C-15A/B	C-15 Rep
	8/7/2006	8/7/2006	8/7/2006	8/9/2006	8/8/2006	8/8/2006	8/8/2006
Total Organic Carbon (TOC) (mg/kg)	102,000	39,400	36,000	166,000	79,700	66,000	NA
Percent Total Solids (%)	18.75	40.93	44.77	14.24	22.57	26.18	24.85
Sediment Particles, Clay (%)	53.95	23.76	NA	47.08	36.32	43.58	42.64
Sediment Particles, Gravel (%)	0	0	NA	0	0	0	0
Sediment Particles, Sand (%)	2.81	46.54	NA	8.18	25.76	19.13	21.42
Sediment Particles, Silt (%)	43.24	29.7	NA	44.74	37.92	37.29	35.93

< Less than the reporting limit

NA Not analyzed

4.1.3.1 Nitrogen

Analysis was conducted for key nitrogen constituents including ammonia, nitrate-nitrogen, nitrite-nitrogen, and TKN. LDEQ surface water quality standards require the maintenance of the naturally occurring range of nitrogen-phosphorous ratios.

Ammonia values ranged from < 0.05 mg/L to 0.46 mg/L throughout the four sampling events at all sampling locations. The highest concentrations measured were 0.46 mg/L and 0.31 mg/L during the second sampling event at Sites C-8 and C-13, respectively.

Nitrate-Nitrogen values were higher in winter 2006 compared to other sampling times. The highest concentrations were at Site C-5. Nitrate-Nitrogen concentrations were 1.29 mg/L and 1.00 mg/L at C-5 in winter and spring 2006, respectively.

Nitrite-Nitrogen concentrations were very stable during the four sampling events with a range from < 0.02 mg/L to 0.08 mg/L during the study for all locations. TKN values ranged from 0.74 mg/L at C-5 in winter 2006 to 2.63 mg/L at C-11 in January 2006.

4.1.3.2 Total Phosphorus

LDEQ surface water quality standards require the maintenance of the naturally occurring range of nitrogen-phosphorous ratios. In summer 2005 and winter 2006, TP values were higher at C-1 to C 10 (values ranged from 0.11 to 0.48 mg/L) compared to C -11 to C-15 (values ranged from 0.08 to 0.18 mg/L). In spring 2006, TP concentrations at C-1 to C-10 decreased, and were more similar to values from C-11 to C-15. TP values increased from spring to summer 2006 at sites C-1 to C-10. The values were higher when compared with TP values at C-11 to C-15.

4.1.3.3 Other Parameters

BOD5 values ranged from <3 mg/L to 6 mg/L throughout the four sampling events at all sampling locations. No seasonal trends were apparent. Location C-5 had <3 mg/L BOD5 for all four sampling events. TSS values ranged from 8 mg/L to 187 mg/L with highest values occurring during winter 2006. VSS values ranged from 3 mg/L to 33 mg/L with highest values generally occurring during winter 2006. Chlorophyll *a* values ranged from <0.010 to 0.107 mg/L; values were higher at locations C-1 through C-10 than at locations C-11 through C-15.

4.1.4 QA/QC

QA/QC requirements for this project were described in the approved Quality Assurance Project Plan titled *QAPP for Field Sampling for Assessment of Dissolved Oxygen, Physical Habitat, and Biological Characteristics for Man-Made Canals and Unaltered Streams in Terrebonne Basin, Louisiana* (EPA, 2005; EPA, 2006a; EPA, 2006b).

4.1.4.1 Sampling and Analytical Precision

Duplicate samples were collected to estimate variability between samples collected at the same time in the same manner. Measurement quality objectives (MQOs) for relative percent difference (RPD) were established as <20 percent. For some nutrient measurements near detection limits, MQOs were expanded to 50 percent when measurements are <10X but >2X the detection limit of the method and 100 percent when values are <2X the method detection limit. Duplicate results for each critical measurement are summarized in Table 4-16. MQOs were met for all duplicate samples reported at levels above detection limits. Results flagged with an asterisk indicate that samples were analyzed beyond the established hold time. Hold times for nitrates were set at 48 hours in the QAPP but the method states that if both nitrate and nitrite are being measured, the samples can be held up to 28 days.

4.1.4.2 Accuracy of Laboratory Measurements

Accuracy of laboratory analyses was evaluated by the comparison of the percent recovery of laboratory control samples of known concentrations to control limits defined in the methods. QA/QC sample results were not reported with laboratory results. Failures to meet laboratory acceptance criteria for hold times, matrix spikes, continuing calibrations and laboratory control samples are noted on each individual laboratory report narrative, and summarized as follows:

- Summer 2005: The BOD analyses for samples C-11A and C-12A were not acceptable due to failure of laboratory control samples.

- Winter 2006: The TKN analysis for sample C-13B was not acceptable due to failure of laboratory control samples. The COD analyses for samples C-13B, C-14B and C-15B were not acceptable due to matrix interference. The TOC analysis for sample C-13B was not acceptable due to failure of the matrix spike recovery.

4.1.4.3 Biological QA/QC

Benthic macroinvertebrate laboratory procedures were performed in accordance with the biological QA/QC requirements of the approved QAPP. Sorting efficiency and taxonomic identification efficiency were within acceptable limits. Detailed QA/QC information is provided in Appendices H and I. Fish collection procedures and taxonomic identification QA/QC were performed in accordance with the approved QAPP.

4.1.5 Habitat

Habitat assessments were conducted in summer 2005 and 2006 at Sites C-1 to C-10. These sites were mainly surrounded by Forested Wetland. Black willow, cypress trees, and shrubs were the dominant riparian vegetation. Large wood debris was observed at most sites. Submerged, emergent, and floating aquatic vegetation was moderately diverse, abundant and varied in composition at sites C-1 to C-10 (see details in section 4.2).

Table 4-16. Duplicate Results/Sampling Precision

Measurement	Analysis Date	Sample ID	Concentration	Duplicate	RPD (%)
Total Phosphorous	8/31/2005	C-7A	0.46 mg/L	0.48 mg/L	4.4
	2/3/2006	C-9B	0.34 mg/L	0.34 mg/L	0
	4/26/2006	C-1C	0.18 mg/L	0.17 mg/L	5.7
	8/17/2006	C-10D	0.15 mg/L	0.14 mg/L	6.9
Ammonia	8/31/2005	C-7A	0.16 mg/L	0.15 mg/L	6.5
	2/6/2006	C-9B	0.07 mg/L	<0.05 mg/L	N/A
	5/2/2006	C-1C	0.16 mg/L	0.17 mg/L	6.1
	9/1/2006	C-10D	<0.05 mg/L*	<0.05 mg/L*	N/A
Total Kjeldahl Nitrogen	8/31/2005	C-7A	1.56 mg/L	1.48 mg/L	5.3
	2/7/2006	C-9B	1.60 mg/L	1.45 mg/L	9.8
	5/3/2006	C-1C	0.95 mg/L	0.98 mg/L	3.1
	8/21/2006	C-10D	0.86 mg/L	0.90 mg/L	4.5
Nitrates	8/24/2005	C-7A	0.02 mg/L*	0.02 mg/L*	0
	1/20/2006	C-9B	53.4 mg/L	53.4 mg/L	0
	5/1/2006	C-1C	0.25 mg/L*	0.27 mg/L*	7.7
	8/11/2006	C-10D	0.04 mg/L*	0.05 mg/L*	22.2
Nitrite	8/17/2005	C-7A	0.03 mg/L*	0.03 mg/L*	0
	1/18/2006	C-9B	0.02 mg/L	0.02 mg/L	0
	4/19/2006	C-1C	0.03 mg/L	0.03 mg/L	0
	8/11/2006	C-10D	<0.02 mg/L	<0.02 mg/L	N/A
Total Suspended Solids	8/19/2005	C-7A	14 mg/L	14 mg/L	0
	1/23/2006	C-9B	141 mg/L	117 mg/L	18.6
	4/24/2006	C-1C	30 mg/L	32 mg/L	6.5
	8/10/2006	C-10D	11 mg/L	11 mg/L	0
BOD, 5-Day	8/17/2005	C-7A	4 mg/L	4 mg/L	0
	1/18/2006	C-9B	5 mg/L	5 mg/L	0
	4/19/2006	C-1C	<3 mg/L	<3 mg/L	N/A
	8/9/2006	C-10D	<3 mg/L	<3 mg/L	N/A
Chlorophyll-a	8/17/2005	C-7A	59.4 µg/L	53.4 µg/L	10.6
	1/18/2006	C-9B	53.4 µg/L	53.4 µg/L	0
	5/15/2006	C-1C	<10 µg/L*	<10 µg/L*	N/A
	8/9/2006	C-10D	32.0 µg/L	34.7 µg/L	8.1

* sample exceeded holding time

For Sites C-11 to C-15, habitat assessments were only conducted once in summer 2006. These sites were surrounded by Non-Forested Wetland. Grasses were the dominant riparian vegetation. Herbaceous vegetation was also present at Site C-14. There was no large woody debris observed at these sites. Emergent aquatic vegetation (e.g., *Spartina patens*, *Spartina alterniflora*, *Juncus romerianus*) were present in every sample. Submerged and floating aquatic vegetation were not observed at sites C-11 to C-15. The habitat assessment forms are included in Appendix G.

4.1.6 Benthic Macroinvertebrates

4.1.6.1 Summer 2005

Results of benthic macroinvertebrate sampling in summer 2005 for sites C-1 to C-10 are presented (along with relevant QA/QC data) in the report from C-K Associates, LLC, attached as Appendix H. Best candidate metrics according to U.S. EPA's Rapid Bioassessment Protocol were calculated for the dipnet samples using EDAS v.3.2XP (TetraTech). When species-specific data for candidate metrics were not available, family-level values were used. The metrics calculated by C-K Associates included Total Taxa, Number of EPT Taxa, Ephemeroptera Taxa, Plecoptera Taxa, Trichoptera Taxa, % EPT, % Ephemeroptera, % Tolerant Taxa, Number of Intolerant Taxa, % Dominant Taxa, % Filter Feeders, % Grazer/Scrapers, Number of Clinger Taxa, and % Clinger Taxa. These metrics are presented but were not used as the basis for developing assocations with dissolved oxygen. Rather, more robust, widely accepted, and comparable metrics (species richness, Shannon-Weiner Diversity Index (H') and density per square meter) were used. Total individuals reported for the 2005 benthic data are based on a 300 organism target count with a multiplier applied, thus reflecting a corrected abundance. The dip net and ponar samples at site C-2 were accidentally composited.

Only the freshwater sites were sampled in 2005. The predominant organisms that were found in the dip net samples were various chironomids, amphipods, *Palaemonetes kadakiensis*, and mayflies (*Caenis*). Similar taxa were found in the petite ponar samples, with the exception of a large abundance of tubificids at C-9 and C-10. Detailed site specific benthic macroinvertebrate results are discussed in sections 4.2 and 5.1.4.

4.1.6.2 Summer 2006

Results of benthic macroinvertebrate sampling in summer 2006 for sites C-1 to C-15 are presented in Appendix I, along with relevant QA/QC data. A detailed description of sorting procedures, subsampling procedures, and sorting efficiency is provided in Sorting Narratives: EcoAnalysts, Inc. Project 857-Terrebonne Basin 2006 (Appendix I). Appendix I also contains an explanation of the benthic macroinvertebrate community metrics ("Metric Output Guidance Document") and information concerning tolerance values, feeding habits, and habitat characteristics for each taxonomic group. For the 2006 benthic data, the total individuals represent the actual number of organisms sorted from a sample using a 300 organism target count, while the corrected abundance reports the estimated total number of invertebrates present in the sample.

There appears to be several distinct communities that were identified that correlate with the salinity/vegetation classification of the fifteen study sites. Some potentially important taxa that might define the groups are: (1) marine organisms (including *Palaemonetes pugio*); (2) the freshwater vegetation-dwelling group (including *Caenis diminuta*); (3) the freshwater sediment-dwelling group (including *Campsurus*); and (4) a tolerant group (dominated by oligochaete worms and some other organisms.). One sample (C-15 sediment) was atypical and contained only two organisms. Detailed site specific benthic macroinvertebrate results are discussed in sections 4.2, 5.1.4, and 5.2.4.

In describing the results of the benthic macroinvertebrate sampling, the terms low, moderate, or high are used to characterize species richness and abundance. This categorization was primarily based on the 2006 benthic results because data were available from all 15 sites.

For dip net samples from C-1 through C-10, abundance and species richness were defined as follows:

- Abundance (total number of individuals)
  - > 7,411 (high)
  - 718 – 7,411 (moderate)
  - ≤ 717 (low)
- Species richness (number of species)
  - > 38 (high)
  - 19 – 38 (moderate)
  - ≤ 18 (low)

For ponar samples from C-1 through C-10, abundance and species richness were defined as follows:

- Abundance (total number of individuals)
  - > 371 (high)
  - 71 – 371 (moderate)
  - ≤ 70 (low)
- Species richness (number of species)
  - > 23 (high)
  - 13 – 23 (moderate)
  - ≤ 12 (low)

For dip net samples from C-11 through C-15, abundance and species richness were defined as follows:

- Abundance (total number of individuals)
    - > 152 (high)
    - 87 – 152 (moderate)
    - ≤ 86 (low)

- Species richness (number of species)
    - NA (high)
    - > 14 (moderate)
    - 14 (low)

For ponar samples from C-11 through C-15, abundance and species richness were defined as follows:

- Abundance (total number of individuals)
    - NA (high)
    - > 11 (moderate)
    - ≤ 11 (low)

- Species richness (number of species)
    - NA (high)
    - > 4 (moderate)
    - ≤ 4 (low)

Since the benthic macroinvertebrate assessment was performed by different contractors in 2005 and 2006, the calculation of community metrics between the two years was verified by performing spot checks of the reported results.

4.1.7 Fish

4.1.7.1 Freshwater and Mixed Sites

Fish were collected at Sites C-1 to C-10 during July 31 to August 3, 2006. Approximately 1,307 specimens representing 24 species of finfish were collected (Table 4-17). All of the specimens were primarily freshwater species. The ecological affinity (freshwater, estuarine, estuarine-marine, or marine) of the fish species collected, as presented in the table, were based on the categories established by Conner and Day (1987). Spotted Gar represented the largest percentage of the specimens by number caught at 29 percent. Other common species included Largemouth bass (9.9 percent), Common bluegill (10.0 percent), Gizzard shad (14.9 percent) and Striped Mullet (13.2 percent).

The number of species collected from Sites C-1 to C-10 ranged from 8 to 15. Sites C-2, C-4, C-7, and C-8 had 15 fish species present, while Sites C-1 and C-9 had the fewest species. Appendix J contains the details of the fish data at sites C-1 through C-10 (including water quality data).

4.1.7.2 Saline Sites

For the three days of sampling at sites C-11 to C-15, a total of fifteen trawl samples and eight gill net samples were collected. Approximately 3,385 specimens representing 27 species of finfish were collected. All of the specimens were primarily marine or estuarine species. Table 4-18 contains a list of the finfish collected at the five sites during August 7 to 9, 2006, with their ecological affinity.

The trawl sampling collected 3,334 specimens and 23 species of finfish, while the gill net samples collected 52 specimens and eight species of finfish. The gill nets collected the larger size fish and more of the sportfish. Tables 4-19 and 4-20 show the finfish collected in the trawl and gill net sampling, respectively. Bay anchovy represented the largest percentage of the specimens by number caught at 86 percent. Other common species included Atlantic croaker (4.7 percent), pinfish (1.6 percent), gafftopsail catfish (1.5 percent) and spadefish (1.4 percent). Sportfish were not common in the trawl samples due in part to the type of sample equipment used and in part to the areas trawled not being ideal sportfishing habitat.

Sites C-12 and C-13 had similar numbers of species and specimens. Site C-12 had 20 species and 1,133 specimens, while Site C-13 had 1,162 specimens and 16 species of fish. Conversely, Site C-15 showed the fewest number of specimens with 104.

The trawl collected many more specimens and species of fish than the gill nets. With the small mesh size of the cod end, small juveniles were also able to be collected providing some indication of successful spawning of seatrout, croaker and silver perch in the Terrebonne Basin. The gill nets were able to capture the larger fish and sportfish; however, the most common fish caught by the gill net were the hardhead catfish and the gafftopsail catfish. The trawl samples collected 3,334 individuals and 23 species, while the gill nets collected 52 individuals and eight species. The fish sampling data sheets are provided in Appendix K.

Table 4-17. Fish Species and Number of Individuals Collected from Locations C-1 through C-10, Terrebonne Basin, Louisiana

Organism	Common Name / Ecological Affinity	Number of Individuals										Total Individuals
		C-1	C-2	C-3	C-4	C-5	C-6	C-7	C-8	C-9	C-10	
Micropterus salmoides	Largemouth bass (FW)	5	21	12	18	20	28	4	8		13	129
Lepomis macrochirus	Common Bluegill (FW)	10	8	17	22	6	20	5	32	1	10	131
Pomoxis annularis	White Crappie (FW)	1										1
Ictiobus bubalus	Smallmouth Buffalo (FW)	8	7	1	16		1	8				41
Lepomis megalotis	Longear Sunfish (FW)	11	2		7				1			21
Aplodinotus grunniens	Freshwater Drum (FW)	1	4		12		1	3	7			28
Dorosoma petenense	Threadfin Shad (FW)	60+										60+
Dorosoma cepedianum	Gizzard Shad (FW)	22	28	6	43	6	20		14	28	28	195
Mugil cephalus	Striped Mullet (EM)	2	11	2	3	13	27	39	4	66	5	172
Alosa chrysochloris	Skipjack herring (FW)	1						1		1	1	4
Hypophthalmichthys molitrix	Silver Carp (FW)	1										1
Pomoxis nigromaculatus	Black Crappie (FW)		8	1	8	2	4	1	13		3	40
Cyprinus carpio	Common Carp (FW)		4	1	4	1	1	1	1			13
Anguilla rostrata	American Eel (FW)		1		1			1	1	2		6
Lepisosteus oculatus	Spotted Gar (FW)		18	34	50	66	48	51	39	17	57	380
Amia calva	Bowfin (FW)		2		1	13	1	2	1	2	2	24
Lepomis gulosus	Warmouth (FW)		1		10							11
Lepomis microlophus	Redear (FW)		1		2	1	16	2	1			23
Ictalurus punctatus	Channel catfish (FW)		2		2			1	1	2	4	12
Elops saurus	Ladyfish (EM)					1		2				3
Ictalurus furcatus	Blue Catfish (FW)						2				2	4
Pylodictis olivaris	Flathead catfish (FW)							1	1			2
Anchoa mitchilli	Bay anchovy (EM)								5			5
Notemigonus crysoleucas	Golden Shiner (FW)										1	1
TOTALS	**TOTAL**	**122**	**118**	**74**	**199**	**129**	**169**	**122**	**129**	**119**	**126**	**1,307**

FW = Freshwater

EM = Estuarine-Marine (after Conner and Day 1987)

Table 4-18. Fish Species and Number of Individuals Collected from Locations C-11 through C-15, Terrebonne Basin, Louisiana

Organism	Common Name/Ecological Affinity	Number of Individuals					Total Individuals
		C-11	C-12	C-13	C-14	C-15	
Carcharhinus leucas	Bull Shark (M)			4	2		6
Dasyatis americana	Southern Stingray (M)		3		1		4
Elops sarus	Ladyfish (EM)		2				2
Brevoortia patronus	Gulf Menhaden (EM)		1				1
Anchoa mitchilli	Bay Anchovy (EM)	28	1,022	1,063	758	54	2,925
Arius felis	Hardhead Catfish (EM)	1	16	8		14	39
Bagre marinus	Gafftopsail Catfish (EM)	2	27	3	16	5	53
Opsanus beta	Gulf Toadfish (M)	1	3	1		2	7
Syngnathus louisianae	Chain Pipefish (EM)		1				1
Selene vomer	Look Down (M)		1				1
Archosargus probatocephalus	Sheepshead (EM)		1	2		2	5
Lagodon rhomboides	Pinfish (E)	7	12	34		4	57
Bairdiella chrysoura	Silver Perch (EM)			3	1		4
Cynoscion arenarius	Sand Seatrout (EM)			1	6		7
Cynoscion nebulosus	Speckled Trout (EM)	1	1	1		1	4
Cynoscion sp.	Unknown Seatrout (EM)			16	2		18
Leiostomus xanthurus	Spot (EM)		2	7		2	11
Micropogonias undulatus	Atlantic Croaker (EM)	93	19	9	25	12	158
Pogonius cromis	Black Drum (EM)				1		1
Sciaenops ocellatus	Red Drum (EM)				1		1
Chaetodipterus faber	Spadefish (EM)	26	10	6		6	48
Chasmodes bosquianus	Striped Blenny (M)			1			1
Gobioides broussoneti	Violet Goby (E)		1	1	1		3
Scomberomorus maculatus	Spanish Mackerel (M)			1			1
Citharichthys spilopterus	Bay Whiff (EM)		4				4
Paralichthys lethostigma	Southern Flounder (EM)		1				1
Symphurus plagiusa	Blackcheek Tonguefish (M)		2				2
Sphoeroides parvus	Least Pufferfish (M)	3	4		11	2	20
TOTALS		162	1,133	1,161	825	104	3,385

E = Estuarine EM = Estuarine-Marine M = Marine (after Conner and Day 1987)

Table 4-19. Fish Species and Number of Individuals Collected from Locations C-11 through C-15 by Trawling, Terrebonne Basin, Louisiana

Organism	Common Name / Ecological Affinity	Number of Individuals C-11				Number of Individuals C-12				Number of Individuals C-13				Number of Individuals C-14				Number of Individuals C-15				Total Individuals
		Trawl 1	Trawl 2	Trawl 3	Total	Trawl 1	Trawl 2	Trawl 3	Total	Trawl 1	Trawl 2	Trawl 3	Total	Trawl 1	Trawl 2	Trawl 3	Total	Trawl 1	Trawl 2	Trawl 3	Total	
Carcharhinus leucas	Bull Shark (M)																					
Dasyatis americana	Southern Stingray (M)					3			3							1	1					4
Elops sarus	Ladyfish (EM)					2			2													2
Brevoortia patronus	Gulf Menhaden (EM)																					
Anchoa mitchilli	Bay Anchovy (EM)			28	28	345	470	207	1,022	376	411	276	1,063	255	329	174	758		48	6	54	2,925
Arius felis	Hardhead Catfish (EM)						5	2	7													7
Bagre marinus	Gafftopsail Catfish (EM)		2		2	1	11	9	21			2	2	7	3	6	16			5	5	46
Opsanus beta	Gulf Toadfish (M)		1		1			3	3	1										2	2	6
Syngnathus louisianae	Chain Pipefish (EM)						1		1													1
Selene vomer	Look Down (M)					1			1													1
Archosargus probatocephalus	Sheepshead (EM)							1	1			2	2					1		1	2	5
Lagodon rhomboides	Pinfish (E)	2	2	3	7	5	5	2	12	12	14	8	34					3		1	4	57
Bairdiella chrysoura	Silver Perch (EM)										2	1	3			1	1					4
Cynoscion arenarius	Sand Seatrout (EM)											1	1	2	1	3	6					7
Cynoscion nebulosus	Speckled Trout (EM)					1			1			1	1						1		1	3
Cynoscion sp.	Unknown Seatrout (EM)										9	7	16		2		2					18
Leiostomus xanthurus	Spot (EM)							2	2	1	1	5	7					1	1		2	11
Micropogonias undulatus	Atlantic Croaker (EM)	41	48	4	93	10	7	2	19	3	3	3	9	11	6	8	25	1	10	1	12	158
Pogonius cromis	Black Drum (EM)																					
Sciaenops ocellatus	Red Drum (EM)																					
Chaetodipterus faber	Spadefish (EM)	8	18		26	1	4	3	8	1	2	3	6						4	2	6	46
Chasmodes bosquianus	Striped Blenny (M)									1			1									1
Gobioides broussoneti	Violet Goby (E)							1	1	1			1			1	1					3
Scomberomorus maculatus	Spanish Mackerel (M)											1	1									1
Citharichthys spilopterus	Bay Whiff (EM)					2	2		4													4
Paralichthys lethostigma	Southern Flounder (EM)							1	1													1
Symphurus plagiusa	Blackcheek Tonguefish (M)					1	1		2													2
Sphoeroides parvus	Least Pufferfish (M)	1		2	3		3	1	4					6	3	2	11		2		2	20
TOTALS		**52**	**71**	**37**	**160**	**372**	**509**	**234**	**1,115**	**396**	**442**	**310**	**1,147**	**281**	**344**	**196**	**821**	**6**	**66**	**18**	**90**	**3,333**

E = Estuarine EM = Estuarine-Marine M = Marine (after Conner and Day 1987)

Table 4-20. Fish Species and Number of Individuals Collected from Locations C-11 through C-15 Collected Using Gill Nets, Terrebonne Basin, Louisiana

Organism	Common Name / Ecological Affinity	Number of Individuals			Number of Individuals			Number of Individuals			No. of Individuals		No. of Individuals		Total Individuals
		C-11			C-12			C-13			C-14		C-15		
		GN 1	GN 2	Total	GN 1	GN 2	Total	GN 1	GN 2	Total	GN 1	Total	GN 1	Total	
Carcharhinus leucas	Bull Shark (M)							2	2	4	2	2			6
Dasyatis americana	Southern Stingray (M)														
Elops sarus	Ladyfish (EM)														
Brevoortia patronus	Gulf Menhaden (EM)				1		1								1
Anchoa mitchilli	Bay Anchovy (EM)														
Arius felis	Hardhead Catfish (EM)		1	1	5	4	9	5	3	8			14	14	32
Bagre marinus	Gafftopsail Catfish (EM)					6	6	1		1					7
Opsanus beta	Gulf Toadfish (M)														
Syngnathus louisianae	Chain Pipefish (EM)														
Selene vomer	Look Down (M)														
Archosargus probatocephalus	Sheepshead (EM)														
Lagodon rhomboides	Pinfish (E)														
Bairdiella chrysoura	Silver Perch (EM)														
Cynoscion arenarius	Sand Seatrout (EM)														
Cynoscion nebulosus	Speckled Trout (EM)		1	1			1								2
Cynoscion sp.	Unknown Seatrout (EM)														
Leiostomus xanthurus	Spot (EM)														
Micropogonias undulatus	Atlantic Croaker (EM)														
Pogonius cromis	Black Drum (EM)										1	1			1
Sciaenops ocellatus	Red Drum (EM)										1	1			1
Chaetodipterus faber	Spadefish (EM)				2		2								2
Chasmodes bosquianus	Striped Blenny (M)														
Gobioides broussoneti	Violet Goby (E)														
Scomberomorus maculatus	Spanish Mackerel (M)														
Citharichthys spilopterus	Bay Whiff (EM)														
Paralichthys lethostigma	Southern Flounder (EM)														
Symphurus plagiusa	Blackcheek Tonguefish (M)														
Sphoeroides parvus	Least Pufferfish (M)														
TOTALS		**0**	**2**	**2**	**8**	**10**	**19**	**8**	**5**	**13**	**4**	**4**	**14**	**14**	**52**

E = Estuarine EM = Estuarine-Marine M = Marine (after Conner and Day 1987) GN = Gill net

Water quality data was collected concurrently with the fish sampling at each sample site. Temperature (°C), specific conductance (mS/cm), salinity (ppt), DO (mg /L), pH and Secchi disc depth (inches) were collected at the mid-depth of the waterway prior to collecting the fish samples. The highest salinity reading was recorded at C-12 at 23.9 ppt, while the lowest salinity reading was found at C-14 at 10.0 ppt. The DO levels ranged from 4.74 to 7.05 mg /L. The water quality data are included as Table 4 of Appendix J. The field survey forms and field data sheets are included in Appendix K.

The Shannon-Weiner Diversity Index (H') was calculated for each site and includes data from all sampling methods (e.g., trawl and gill net samples were combined). For the freshwater and low salinity sites C-1 to C-10, H' ranged from 1.78 to 3.24 bits per individual. Site C-2 had the highest diversity and Site C-9 had the lowest diversity. For the high salinity waterbodies C-11 to C-15, species diversity index was low at Sites C-12, C-13, C-14 with H' values of 0.79, 0.68, 0.61, respectively. Shannon-Weiner Diversity Index was 1.84 at Site C-11, and 2.37 at Site C-15.

4.2 Site Specific Results

4.2.1 Site C-1

Site C-1, Choctaw Bayou, is an intermediate-sized stream in a forested wetland area. The site was probably dredged in the past, as little habitat was evident and the substrate appeared to be largely clay.

The average DO at Site C-1 was above 5 mg/L in summer 2005. The standard deviation at this sampling time is 1.8 mg/L. The average DO value increased to 7.7 mg/L in winter 2006 with standard deviation of 0.6 mg/L. The value decreased to 4.5 mg/L in spring 2006, and increased to 5.7 mg/L in summer 2006.

The minimum DO values were below 5 mg/L in summer 2005 (2.43 mg/L), summer 2006 (2.82 mg/L), and spring 2006 (3.58 mg/L). In winter 2006, the minimum DO value was 6.76 mg/L.

Results of surface water chemical analysis showed that ammonia concentrations ranged from 0.1 to 0.18 mg/L during the four sampling events. BOD5 was only detected in summer 2005 at 5 mg/L. Chlorophyll-*a* was 0.0251 and 0.0196 mg/L in the first two sampling events, and was not detected (< 0.010) in spring 2006. The value reported was 0.0267 mg/L in summer 2006. Nitrate-N was detected in winter 2006 at 0.27 mg/L, and in spring 2006 at 0.25 mg/L. Nitrite-N values ranged from 0.03 to 0.08 mg/L. TP was lowest in winter 2006 at 0.17 mg/L and highest in summer 2005 at 0.22 mg/L. TKN values were stable and averaged 0.97 mg/L. TSS ranged from 23 to 33 mg/L.

Total Organic Carbon (TOC) in sediments was 13300 mg/kg in summer 2005 and 6860 mg/kg in spring 2006. In summer 2005, percent total solids was 58.19 percent. Sediment particles consisted of 76.7 percent clay, 14.93 percent silt, 8.37 percent sand, and < 0.01 percent gravel. In April 2006, percent total solids was 54.05 percent. Sediment particles consisted of 63.7 percent clay, 30.09 percent sand, 6.21 percent silt.

Habitat assessment was conducted in two summer sampling events at site C-1. In summer 2005, the site was surrounded by forested wetland and the I-10 corridor. Trees and shrubs were the dominant riparian vegetation. There was approximately 60 m^2 large woody debris present. Emergent alligatorweed was present in 5 percent of the sample reach. Coverage occurred near the shorelines. There was no submerged and floating aquatic vegetation present. In summer 2006, the woody debris covered area did not change. There was no submerged, emergent, and floating aquatic vegetation present at the beginning of August, and emergent alligatorweed was present in 5 percent of the samples in late August.

In summer 2005, there were a total of 63 individuals representing 13 species in the Dip net samples collected from site C-1. The most abundant taxa in Dip net samples were Chironomidae, Polypedilum, and *Palaemonetes kadiakensis*. The Shannon-Weiner diversity was 2.67 bits and density was 20.32/m^2. For Petite Ponar samples, 10 individuals representing 4 species were collected. The most abundant taxa in Petite Ponar samples were Chironomidae and *Helobdella*. The Shannon-Weiner diversity in bits was 1.69. Density was 0.70/m^2.

In summer 2006, there were a total of 57 individuals representing 18 species in the Dip net samples collected from site C-1. The Shannon-Weiner diversity was 3.39 bits. For Petite Ponar samples, 91 individuals representing 18 species were collected. The Shannon-Weiner diversity in bits was 2.77.

The Dip net sample in 2006 had low abundance for a vegetation sample (57/sample) and low richness (18 taxa). The chironomid midge *Glyptotendipes* sp. (33.3 percent) was the most abundant taxon in the sample. *Glyptotendipes* are common among the sediments of very organic slow moving waters. Larvae of some species live in the tissues of aquatic vegetation, upon which they feed.

The water boat men, Corixidae (10.5 percent), were also abundant in the sample. Corixids are typically collected from non-flowing or very slow-flowing waters. They can vacate inhospitable aquatic habitats by flying out of the water and disperse for considerable distances. They breath atmospheric oxygen in a bubble they carry, so they are unaffected by low DO concentrations.

The amphipod, *Hyalella* sp. (10.5 percent) was also abundant in the sample. *Hyallella* is tolerant to high temperatures of hot springs, high mineral concentrations and salinity. Although not exceptionally tolerant to low DO concentrations, they are tolerant to high temperature, which reduces the solubility of oxygen in water.

The Ponar sample in 2006 had moderate abundance (91/sample) for a Ponar Grab and moderate richness (18 taxa). The Tubificidae was by far the most abundant (50.5 percent) taxon. Tubificids include many tolerant species including some taxa that are very tolerant to low DO and salinity. They are often the dominant taxa in rich organic environment and in estuaries. The family includes some of the most tolerant worm species known, such as *Limnodrilus hoffmeisteri* and *Tubifex tubifex*.

The chironomid midge, *Cladopelma* (9.9 percent) was the second most-abundant taxon in the sample. They are usually found amid fine sediments and some species in the genus are tolerant of very low oxygen concentrations.

Cladotanytarsus (8.8 percent) is also a chironomid midge. Larvae are tolerant to salinity and other stressors. Some species are very sensitive to acid water, but other species in this group show increased success in at acidic pH. Some species are tolerant to metals and found in hot springs.

A total of 122 individuals representing eleven fish species were collected at Site C-1 in 2006. All of the specimens were primarily freshwater species. Table 4-17 contains a list of finfish collected at Site C-1. Threadfin shad represented the largest number of the specimens with a total number of more than fifty. Other species included Largemouth bass (5 specimens), Common bluegill (10 specimens), White crappie (1 specimen), Smallmouth buffalo (8 specimens), Longear sunfish (11 specimens), freshwater drum (1 specimen), Gizzard shad (22 specimens), Stripped mullet (2 specimens), Skipjack herring (1 specimen), and Silver carp (1 specimen). The Shannon-Weiner Diversity Index of fish species at C-1 was 2.33 bits per individual.

4.2.2 Site C-2

Site C-2, Upper Grand River, is a large-sized stream in a forested wetland area. It was adjacent to an area of cleared land and near some hunting and fishing camps. Despite these indications of impact, the site was retained as it was also an LDEQ site.

The average DO at Site C-2 was only below 5 mg/L in summer 2006. Although the average DO value is 6.7 mg/L, standard deviation is 3.7 mg/L in summer 2005. The average DO value increased to 9.0 mg/L in winter 2006 with standard deviation of 0.4 mg/L. The value decreased to 7.0 mg/L in spring 2006, and further decreased to 3.3 mg/L in summer 2006.

The minimum DO values were below 5 mg/L during summer 2005 (0.13 mg/L) and summer 2006 (1.46 mg/L). In winter 2006, the minimum DO value was 8.3 mg/L. The minimum value was 5.0 mg/L in spring 2006.

In surface water samples, ammonia was detected at 0.14, 0.12, and 0.08 mg/L in summer 2005, winter and summer 2006, respectively. BOD5 values were 3 mg/L in summer 2005 and 5 mg/L in spring 2006; values were below detection the limit in the other two sampling events. Chlorophyll-*a* increased from 0.0251 and 0.0196 mg/L in summer 2005 and winter 2006 to 0.25 mg/L in spring 2006, then decreased to 0.0214 mg/L in summer 2006. Nitrate-N and Nitrite-N ranged from non-detect to 0.03 mg/L. TP ranged from 0.19 to 0.33 mg/L during the four sampling events. The range of TKN was between 0.86 in summer 2006 and 1.37 mg/L in summer 2005. TSS fluctuated from 48 mg/L in summer 2005 to 83 mg/L in winter 2006. The value dropped to 34 mg/L in spring 2006, and summer 2006.

Total Organic Carbon (TOC) in sediments was 23,900 mg/kg in summer 2005 and 14,700 mg/kg in spring 2006. In summer 2005, percent total solids was 50.18 percent. Sediment particles consisted of 67.59 percent sand, 20.01 percent clay, 12.41 percent silt, and < 0.01 percent gravel.

In April 2006, percent total solids was 59.90 percent. Sediment particles consisted of, 58.10 percent sand, 30.86 percent silt, and 11.05 percent clay.

Habitat assessment was conducted in two summer sampling events at site C-2. In summer 2005, the Site was surrounded by forested wetland and large area of disturbed land, e.g. cleared fenced-in area (see Section 2.4). Shrubs were the dominant riparian vegetation. There was approximately 15 m^2 large woody debris present. Submerged *Elodea* was present in 20 percent of the sample reach. Thirty percent of the sample reach had emergent aquatic vegetation, which was comprised of 20 percent alligatorweed and 10 percent cattails. Total floating vegetation (hyacinth 30 percent, duckweed 2 percent, and *Salvinia* sp. 8 percent) was present in 40 percent of the sample reach. Coverage occurred near the shorelines. In summer 2006, there was approximately 10 m^2 large woody debris. Submerged aquatic vegetation was present in 20 percent of the sample reach with 10 percent *Elodea* sp. and 10 percent *Hydrilla* sp. Fifteen percent of the sample reach had emergent aquatic vegetation, which was comprised of 10 percent alligatorweed and 5 percent cattails. Floating water hyacinth was present at 30 percent of the sample reach.

In summer 2005, the petite ponar sample and dip net sample were composited. During the sorting process, the ponar sample and dip net sample were inadvertently combined during subsampling. There were a total of 557 individuals representing 38 species in the sample collected from site C-2. The Shannon-Weiner diversity in bits was 3.59. Density was 179.68/m^2. The most abundant taxa were *Hyalella azteca*, Tubificidae, and *Palaemonetes kadiakensis*.

In summer 2006, there were 717 individuals representing 38 species in the Dip net samples collected from C-2. The Shannon-Weiner diversity was 3.91 bits. For the Petite Ponar samples, 79 individuals representing 18 species were collected. The Shannon-Weiner diversity was 2.86 bits.

The Dip net sample in 2006 had a low abundance for a vegetation sample (~700/sample) and moderate richness (38 taxa). The chironomid midge, *Parachironomus* sp. (27.6 percent) was the most abundant taxon in the sample. *Parachironomus* occur in a wide variety of lentic and lotic ecosystems. Larvae of some species are very tolerant to stressors such as sewage and other pollutants, whereas other species are sensitive stream dwellers.

The Naidid oligochaete worm, *Dero* sp. (10.3 percent) was also an abundant taxon in the sample. Members of this group of worms have respiratory pigments that help them survive periods of very low DO concentration. *Dero* has posterior gills that help increase the respiratory surface area to further enhance respiration in low oxygen conditions. The posterior end of the worm is stuck out of the burrow and waved about to move water over the gills, preventing localized oxygen depletion.

The caenid mayfly *Caenis diminuta* (8.5 percent) was the third most abundant taxon in the sample. Mayflies often indicate clear cold waters with high DO concentrations. However, the caenids are an exception and can be found in warmer waters with lower oxygen concentrations. Their gills are highly branched and very effective at gas exchange. The anterior gills are modified to form an operculum that covers and protects the delicate functional gills from abrasion by sediment. Although sediment tolerant, they require stable substrata to cling to and are ineffective burrowers. Their dominance in this sample may be related to the habitat provided by the vegetation.

The Ponar sample had moderate abundance (79 individuals) for a Ponar grab and moderate taxa richness (18). The most abundant taxon was the polymitarcid mayfly, *Campsurus* sp. (44.3 percent). The larvae construct U-shaped burrows in fine sediments of freshwaters and may become very abundant under certain conditions. In tropical lakes contaminated with bauxite clays, densities may be as high as 1,200 larvae/m^2. By undulating their bodies within their burrows, they pull oxygenated water through their burrows and when abundant, they may greatly increase the amount of DO moving though the sediment.

The predacious midges, Ceratopogoniidae (19.0 percent), were the second most abundant taxon in the Ponar sample. As the name suggests, they are predators, both as larvae and adults. They are often associated with fine sediments (sand or silt). They move through the sediment without constructing permanent burrows and feed on smaller, relatively sessile invertebrates—or the eggs of larger taxa.

Limnodrilus hoffmeisteri (6.3 percent) is an oligochaete worm with cosmopolitan distribution. It has been collected from sediment-laden backwaters of mid-sized rivers, large rivers and estuaries. *L. hoffmeisteri* are tolerant to some salinity (up to 10 ppt). They seem to show increased success at low levels of salinity, which also seems to increase their tolerance to other stressors. Metabolism of the species can change according to interstitial DO concentrations; when concentrations are higher metabolism increases, when they are lower, metabolism decreases, but assimilation efficiencies increase. Hemoglobin pigments may allow the worms to store some oxygen for short periods of anaerobic metabolism. They are considered to be very tolerant to many stressors.

A total of 118 individuals representing fifteen fish species were collected at Site C-2 in 2006. All of the specimens were primarily freshwater species. Table 4-17 contains a list of finfish collected at Site C-2. Gizzard shad, Largemouth bass and Spotted gar represented the largest number of the specimens with 28, 21, and 18 individuals, respectively. Other species included Common bluegill (8 specimens), Black crappie (8 specimens), Smallmouth buffalo (7 specimens), Longear sunfish (2 specimens), freshwater drum (4 specimens), Stripped mullet (11 specimens), Common carp (4 specimens), American Eel (one specimen), Bowfin (2 specimens), Warmouth (1 specimen), Redear (1 specimen), and Channel catfish (2 specimens). The Shannon-Weiner Diversity Index of fish species at C-2 is 3.24 bits per individual.

4.2.3 Site C-3

Site C-3, Pat Bay, is an open water site in an area of forested wetland.

The average DO at Site C-3 was below 5 mg/L at 4.2 mg/L in summer 2005. The average DO value increased to 8 mg/L in winter 2006, and slightly decreased to 7.0 mg/L in spring 2006. The average DO value decreased to 4.6 mg/L in summer 2006 with standard deviation of 2.7 mg/L.

The minimum DO values were below 5 mg/L in summer 2005 (2.0 mg/L), summer 2006 (2.7 mg/L), and spring 2006 (3.6 mg/L). In winter 2006, the minimum DO value was 6.8 mg/L.

Results of surface water analysis showed that ammonia was only detected in winter 2006 at 0.14 mg/L. BOD5 was 6 mg/L in summer 2005, 3 mg/L in winter 2006, and 5 mg/L in spring and summer 2006. Chlorophyll-*a* values were 0.0814 and 0.0374 mg/L in the first two sampling events, and 0.0196 mg/L in spring 2006. The value increased to 0.079 mg/L in summer 2006. Nitrate-N was only detected in winter 2006 at 0.28 mg/L. The highest Nitrite-N value detected was 0.04 mg/L in winter 2006. TP ranged from 0.17 mg/L in spring 2006 to 0.36 mg/L in summer 2006. TKN values were stable and averaged at 1.235 mg/L. TSS fluctuated from 46 mg/L in summer 2005 to 67 mg/L in winter 2006. The value dropped to 42 mg/L in spring 2006, and 29 mg/L in summer 2006.

In April 2006, Total Organic Carbon (TOC) in sediments was 72,600 mg/kg. Percent total solids was 21.97 percent. Sediment particles consisted of 73.76 percent clay, 22.26 percent silt, and 3.98 percent sand.

Habitat assessment was conducted in two summer sampling events at site C-3. In summer 2005, the Site was surrounded by forested wetland. Cypress trees are the dominant riparian vegetation. There was approximately 30 m^2 large woody debris present. Submerged *Elodea* sp. were present in 40 percent of the sample reach, and submerged *Hydrilla* sp. in 20 percent of the sample reach. Total floating vegetation (*Salvinia* sp.) was present in 20 percent of the sample reach. Coverage occurred near the right bank.

In summer 2005, there was a total of 217 individuals representing 16 species in the Dip net samples collected from site C-3. The Shannon-Weiner diversity was 2.78 bits and density was $70/m^2$. The most abundant taxa in Dip net samples were Caenis, *Hyalella azteca*, and *Parachironomus*. For the Petite Ponar samples, there were a total of 43 individuals representing 11 species collected. The Shannon-Weiner diversity was 2.49 bits and Density was $2.99/m^2$. The most abundant taxa in Petite Ponar samples were Caenis and Bivalvia.

In summer 2006, there were a total of 1606 individuals representing 32 species in the Dip net samples collected from site C-3. The Shannon-Weiner diversity was 3.5 bits. For the Petite Ponar samples, 70 individuals representing 18 species were collected. The Shannon-Weiner diversity was 3.66 bits.

The Dip net sample in 2006 had moderate abundance (>1,600 individuals) and moderate taxa richness (32) for a vegetation sample. The chironomid midge, *Parachironomus* sp. (31 percent) was the most abundant taxon in the sample. Larvae of some species are very tolerant, whereas other species are sensitive stream dwellers. The two next most abundant taxa both comprised 12.5 percent of the sample. The Tanypod *Labrundunia* is a predacious Chironomid midge, commonly found among fine sediments and may become dominant in bauxite-contaminated sediments. The naidid oligochaete worm, *Dero* sp. also comprised 12.5 percent of the sample. Members of this group of worms have respiratory pigments and posterior gills that that help them survive periods of very low DO concentration.

The Ponar sample in 2006 had fairly low abundance (70 individuals) and moderate taxa richness (18). Two taxa had an abundance of 12 individuals and two had an abundance of 7 individuals.

The two most abundant taxa were the polymitarcid mayfly, *Campsurus* sp. (17.1 percent) and the Tubificidae (17.1 percent). The caenid mayfly *Caenis diminuta* (10 percent) was the second most abundant taxon in the sample. Mayflies often indicate clear cold waters with high DO concentrations. However, the Caenidae are an exception and can be found in warmer waters with lower oxygen concentrations. Although sediment tolerant, they require stable substrata to cling to and are ineffective burrowers. Their dominance in this sample may be related to the habitat provided by the vegetation. The phantom midge, *Chaoborus* sp. (10 percent) is a predator that resides among benthic sediments by day and vertically migrates as plankton after dusk. Larvae are transparent and feed on other zooplankton.

A total of 74 individuals representing eight fish species were collected at Site C-3 in 2006. All of the specimens were primarily freshwater species. Table 4-17 contains a list of finfish collected at Site C-3. Spotted gar represented the largest number of the specimens with 34 samples. Other species included Largemouth bass (12 samples), Common bluegill (17 specimens), Black crappie (1 specimen), Smallmouth buffalo (1 specimen), Gizzard shad (6 samples), Stripped mullet (2 specimens), and Common carp (1 specimen). The Shannon-Weiner Diversity Index of fish species at C-3 was 2.11 bits per individual.

4.2.4 Site C-4

Site C-4, Lower Flat River, is an intermediate stream in an area of forested wetland.

The average DO at Site C-4 was below 5 mg/L at 4.4 mg/L in summer 2005. The average DO value increased to 8.2 mg/L in winter 2006, and slightly decreased to 7.7 mg/L in spring 2006. The average DO value decreased to 3.1 mg/L in summer 2006. The standard deviation was 1.7 mg/L to 2.0 mg/L in the two summers and spring, and was 0.8 mg/L in winter.

The minimum DO values were below 5 mg/L in summer 2005 (1.6 mg/L), summer 2006 (1.4 mg/L), and spring 2006 (4.9 mg/L). In winter 2006, the minimum DO value was 7.1 mg/L.

Results of surface water analysis showed that ammonia concentrations ranged from 0.06 mg/L to 0.5 mg/L with the lowest value detected in spring 2006 and highest value detected during summer 2005. BOD5 was 3 mg/L in winter 2006, 6 mg/L in spring 2006, and was not detected in the other two sampling events. Chlorophyll-*a* was detected in winter 2006 at 0.0374 mg/L and in spring 2006 at 0.0234 mg/L. Nitrate-N continuously increased from 0.13 to 0.38, to 0.42 mg/L in the first three sampling events, and dropped to 0.03 mg/L in summer 2006. Nitrite-N values ranged from 0.03 to 0.05 mg/L. TP ranged from 0.2 mg/L in winter 2006 to 0.29 mg/L in summer 2006. TKN values were stable with an average and standard deviation of 1.09 mg/L and 0.3mg/L. TSS was 20 and 25 mg/L during the two summers and was higher in winter and spring at 40 and 42 mg/L.

In April 2006 at C-4, Total Organic Carbon (TOC) in sediments was 38,300 mg/kg. Percent total solids was 40.42 percent. Sediment particles consisted of 36.34 percent silt, 34.11 percent sand, and 29.55 percent clay.

Habitat assessment was conducted in two summer sampling events at site C-4. In summer 2005, the Site was surrounded by forested wetland. Cypress and gum trees were the dominant riparian vegetation. There was approximately 30 m^2 large woody debris present. There was no submerged and floating aquatic vegetation. Three percent of the sample reach had emergent aquatic vegetation (cattails). Coverage occurred near the shorelines. On August 1, 2006, there was approximately 20 m^2 large woody debris. There was no submerged aquatic vegetation present. Ten percent of the samples had emergent cattails. Floating water hyacinth was present in 5 percent of the sample reach.

In summer 2005, there were a total of 279 individuals representing 20 species in the Dip net samples collected from site C-4. The Shannon-Weiner diversity was 1.49 bits and density was $90/m^2$. By far, the most abundant taxon in Dip net samples was Caenis, *Viriparus georgianus* and *Hyalella azteca* were next in abundance but represented minor members of the community.

For the Petite Ponar samples, 154 individuals representing 24 species were collected. The most abundant taxa in Petite Ponar samples were Tubificidae, Caenis and Chironomidae. The Shannon-Weiner diversity was 3.65 bits and density was $10.72/m^2$.

In summer 2006, there were a total of 382 individuals representing 30 species in the Dip net samples collected from site C-4. The Shannon-Weiner diversity was 3.05 bits. For the Petite Ponar samples, a total of 238 individuals representing 25 species were collected. The Shannon-Weiner diversity was 3.37 bits.

The Dip net sample in 2006 contained 382 invertebrates, from 30 distinct invertebrate taxa, representing low abundance, but moderate species richness. The naidid oligochaete worm, *Dero* sp. (30.75 percent), was the most abundant taxon in the sample. Members of this group of worms can tolerate low oxygen conditions. The caenid mayfly *Caenis diminuta* (23.6 percent) was the second most abundant taxon in the sample. As discussed previously, the Caenidae can be found in warmer waters with lower oxygen concentrations. The naidid oligochaete worm *Bratislavia unidentata* (19.7 percent) was the third most-abundant taxon in the sample. The ecological requirements of the genus *Bratislavia* are not well known because they were originally grouped with a different genus (*Pristina* sp.).

The Ponar sample in 2006 contained 238 invertebrates, from 25 distinct invertebrate taxa, representing moderate abundance, but high species richness for a sediment sample collected with a Ponar grab. The Tubificidae comprised the most abundant taxonomic group in the sample (25.2 percent). The caenid mayfly *Caenis diminuta* (17.2 percent) was the second most abundant taxon in the sample. The predacious midges, Ceratopogonidae (13.9 percent), were the third most abundant taxon in the sample. As the name suggests, they are predators, both as larvae and adults. They are often associated with fine sediments (sand or silt). They move through the sediment without constructing permanent burrows and feed on smaller, relatively sessile invertebrates or the eggs of larger taxa.

A total of 199 individuals representing fifteen fish species were collected at Site C-4 in 2006. All of the specimens were primarily freshwater species. Table 4-17 contains a list of finfish collected at Site C-4. Gizzard shad and Spotted gar represented the largest number of the specimens with 43, and 50 samples, respectively. Other species included Largemouth bass (18 specimens), Common bluegill (22 specimens), Black crappie (8 specimens), Smallmouth buffalo (16 specimens), Longear sunfish (7 specimens), Freshwater drum (12 specimens), Striped mullet (3 specimens), Common carp (4 specimens), American Eel (one specimen), Bowfin (1 specimen), Warmouth (10 specimens), Redear (2 specimens), and Channel catfish (2 specimens). The Shannon-Weiner Diversity Index of fish species at C-4 is 3.17 bits per individual.

4.2.5 Site C-5

Site C-5 is the Bay off of the Lower Grand River. It is in a forested wetland area and was classified as a large stream for this study.

The average DO at Site C-5 was slightly below 5 mg/L at 4.4 mg/L in summer 2005. The average DO value increased to 9.9 mg/L in winter 2006, and decreased to 8.7 mg/L in spring 2006. The average DO value dropped to 3.6 mg/L in summer 2006.

The minimum DO values were below 5 mg/L at 2.9 mg /L and 2.4 mg/L in the two summer sampling events, respectively. In winter 2006, the minimum DO value was 8.6 mg/L. The minimum DO value was 6.8 mg/L in spring 2006.

Results of surface water analysis showed that ammonia concentrations were not higher than 0.1 mg/L and BOD5 was < 3 mg/L in all sampling events. Chlorophyll-*a* was detected in summer 2005 at 0.0205 mg/L and in winter 2006 at 0.0107 mg/L. Nitrate-N was 0.19 mg/L in summer 2005, its values peaked at 1.25 mg/L in winter 2006,and dropped to 1.0 mg/L in spring and 0.35 mg/L summer 2006. Nitrite-N values were 0.06 mg/L in summer 2005, and 0.03 mg/L in all three sampling events in 2006. TP ranged from 0.17 mg/L in spring 2006 to 0.25 mg/L in summer 2006. TKN was 1 mg/L in summer 2005, decreased to 0.74 mg/L in winter 2006, and stayed at this level in summer 2006. TSS was approximately 40 mg/L except in winter 2006 at 70 mg/L.

In April 2006 at site C-5, Total Organic Carbon (TOC) in sediments was 23,600 mg/kg. Percent total solids was 34.65 percent. Sediment particles consisted of 68.60 percent clay and 34.87 percent silt.

Habitat assessment was conducted in two summer sampling events at site C-5. In summer 2005, the Site was surrounded by forested wetland. Black willow trees were the dominant riparian vegetation. There was approximately 20 m^2 large woody debris. Submerged *Hydrilla* sp. was present in 80 percent of the samples. Fifty percent of the sample reach had emergent aquatic vegetation, which was comprised of 20 percent alligatorweed and 5 percent other grass. Total floating vegetation (duckweed 30 percent, and *Salvinia* sp., 70 percent) was present in all sample reaches. Coverage occurred near the shorelines. On August 2, 2006, there was approximately 5 m^2 large woody debris. Submerged aquatic vegetation was present in 40 percent of the sample reach (20 percent *Hydrilla* sp. and 20 percent cattails). Five percent of the sample reach had emergent alligatorweed. Floating water hyacinth was present in 15 percent of the sample reach and floating duckweed was present in 15 percent of the sample reach.

In summer 2005, there were a total of 280 individuals representing 27 species in the Dip net samples collected from site C-5. The Shannon-Weiner diversity was 3.26 bits and density was 90.32/m^2. The most abundant taxa in Dip net samples were *Palaemonetes kadiakensis*, *Hyalella azteca*, and *Biomphalaria havanensis*. For the Petite Ponar samples, 34 individuals representing 9 species were collected. The most abundant taxa in Petite Ponar samples were *Hexagenia bilineata* and Chaoborus. The Shannon-Weiner diversity was 1.71 bits and density was 2.37/m^2.

In summer 2006, there were a total of 7,412 individuals representing 37 species in the Dip net samples collected from site C-5. The Shannon-Weiner diversity was 4.42 bits. For the Petite Ponar samples, 391 individuals representing 29 species were collected. The Shannon-Weiner diversity was 2.82 bits.

The Dip net sample in 2006 contained over 7,000 invertebrates and 37 distinct taxa, which was one of the most diverse samples collected. The sample was so diverse that the dominant three taxa only comprised about 35 percent of the sample (combined).

The chironomid midge, *Parachironomus* sp. (17.6 percent) was the most abundant taxon in the sample. As described previously, *Parachironomus* occur in a wide variety of lentic and lotic ecosystems. The naidid oligochaete worm, *Dero* sp. (10.1 percent), was the second most abundant taxon in the sample. The chironomid midge, *Tanytarsus* sp. (6.8 percent), was the third most-abundant taxon in the sample. *Tanytarsus* are found in a variety of aquatic habitats and may be collected from streams, lakes or estuaries. They may be found in fresh or brackish water and show a preference for sediments with a high ratio of organic to inorganic mater.

The Ponar sample contained 391 invertebrates, representing 29 distinct taxa, which is very diverse for a sediment sample collected with a Ponar grab. The most abundant taxon was the polymitarcid mayfly, *Campsurus* sp. (49 percent). *Limnodrilus hoffmeisteri* (14.4 percent) is an oligochaete worm with cosmopolitan distribution. As discussed previously, it has been collected from sediment laden backwaters of mid-sized rivers, large rivers and estuaries.

A fingernail clam, *Musculium transversum* (10.4 percent), was the third most-abundant taxon in the sample. This species is common in large North American rivers.

A total of 129 individuals representing ten fish species were collected at Site C-5. All of the specimens were primarily freshwater species. Table 4-17 contains a list of finfish collected at Site C-5. Spotted Gar represented the largest number of the specimens with 66 samples. Other species included Largemouth bass (20 specimens), Common bluegill (6 specimens), Black crappie (2 specimens), Gizzard shad (6 specimens), Stripped mullet (13 specimens), Common carp (1 specimen), Bowfin (13 specimens), Redear (1 specimen), and Ladyfish (1 specimen). The Shannon-Weiner Diversity Index of fish species at C-5 is 2.25 bits per individual.

4.2.6 Site C-6

Site C-6, Little Bayou Long/Grande Bayou is an intermediate stream in an area of forested wetland. It is classified as a mixed salinity site based upon the average salinity and vegetation type.

The average DO at Site C-6 was slightly below 5 mg/L at 4.9 mg/L with a standard deviation of 2 mg/L in summer 2005. The average DO value increased to 5.9 mg/L in winter 2006, and to 6.4 mg/L in spring 2006. The average DO value decreased to 4.1 mg/L in summer 2006.

The minimum DO values were below 5 mg/L during all sampling events. The minimum DO value was at 1.9 mg/L and 1.1 mg/L in the two summer sampling events, respectively. In winter 2006, the minimum DO value was 4.2 mg/L. The minimum DO value was 3.1 mg/L during spring 2006.

Results of surface water analysis showed that ammonia concentrations ranged from 0.06 to 0.12 mg/L. The highest concentration was in summer 2006 and the lowest value was in summer 2005. The highest BOD5 value was 4 mg/L in all sampling events. Chlorophyll-*a* was detected in summer 2005 at 0.0358 mg/L and in winter 2006 at 0.0294 mg/L. Its value was lower in spring 2006 at 0.0160 mg/L, and increased to 0.0246 mg/L in summer 2006. Nitrate-N was below the detection limit in summer 2005 and spring 2006, with values of 0.79 and 0.09 in winter and summer 2006, respectively. The highest Nitrite-N value was 0.03 mg/L during the sampling events. TP levels were between 0.44-0.49 mg/L except in winter 2006 at 0.23 mg/L. TKN ranged from 0.79 to 1.48 mg/L. TSS was 18 mg/L in summer 2005, 60 mg/L in winter 2006, 29 and 30 mg/L in spring and summer 2006.

In April 2006 at site C-6, Total Organic Carbon (TOC) in sediments was 53,500 mg/kg. Percent total solids was 42.27 percent. Sediment particles consisted of 48.92 percent clay, 26.00 percent sand, and 25.08 percent silt.

Habitat assessment was conducted in two summer sampling events at site C-6. In summer 2005, the Site was surrounded by forested wetland. Cypress trees were the dominant riparian vegetation. There was no large woody debris present. Submerged *Elodea* and *Hydrilla* sp. were present in 15 percent of the sample reach respectively. Twenty percent of the samples had emergent alligatorweed. Total floating vegetation (water hyacinth 20 percent; duckweed 10 percent, and *Salvinia* sp 10 percent) was present in 50 percent of the sample reach. Coverage occurred near the shorelines. On August 2, 2006, submerged aquatic vegetation was present in 30 percent of the sample reach (15 percent *Hydrilla* sp. and 15 percent *Elodea* sp.). Ten percent of the sample reach had emergent alligatorweed. Floating water hyacinth was present in 30 percent of the sample reach, and floating *Salvinia* sp. was present in 10 percent of the sample reach.

In summer 2005, there were a total of 258 individuals representing 28 species in the Dip net samples collected from site C-6. The Shannon-Weiner diversity was 3.71 bits and density was 83.23/m^2. The most abundant taxa in Dip net samples were *Biomphalaria havanensis, Hyalella azteca*, and Pyralidae. For the Petite Ponar samples 30 individuals representing 11 species were collected. The Shannon-Weiner diversity in bits was 2.66. Density was 431.03/m^2. The most abundant taxa in Petite Ponar samples were Glyptotendipes and Caecidotea.

In summer 2006, there were a total of 5,392 individuals representing 43 species in the Dip net samples collected from site C-6. The Shannon-Weiner diversity was 4.32 bits. For the Petite Ponar samples, 98 individuals representing 12 species were collected. The Shannon-Weiner diversity was 2.77 bits.

The Dip net sample in 2006 had moderate abundance (5,392 individuals) and high richness (43 taxa). The naidid oligochaete worm, *Dero* sp. (19.3 percent) was the most abundant taxon in the sample. The chironomid midge, *Parachironomus* sp. (10.9 percent) was also an abundant taxon in the sample. The naidid oligochaete worm, *Pristina leidyi* (8.9 percent) was the third most abundant taxon in the sample. This is a cosmopolitan species that has been used for sediment toxicity studies. They have been collected from a variety of aquatic habitats, including caves.

The Ponar sample contained a moderate number of invertebrates (98 individuals) and moderate richness (12 taxa) for a sediment Ponar sample. The dominant taxon was the ceratopogonid midge, *Sphaeromias* sp. (34.7 percent). The larvae are predators and achieve very high abundances in sandy fine sediments and mats of benthic algae.

Immature Ceratopogonidae also comprised the second most abundant taxon (19.4 percent). They are predators both as larvae and adults. They are often associated with fine sediments (sand or silt). They move through the sediment without constructing permanent burrows and feed on smaller, relatively sessile invertebrates or the eggs of larger taxa. Mud snails, Hydrobiidae, comprised the third most abundant taxon in the sample (17.4 percent).

A total of 169 individuals representing twelve fish species were collected at Site C-6 in 2006. All of the specimens were primarily freshwater species. Table 4-17 contains a list of finfish collected at Site C-6. Spotted gar represented the largest number of the specimens with 48 specimens. Other species included Largemouth bass (28 specimens), Common bluegill (20 specimens), Black crappie (4 specimens), Smallmouth buffalo (1 specimen), Freshwater drum (1 specimen), Gizzard shad (1 specimen), Striped mullet (27 specimens), Common carp (1 specimen), Bowfin (1 specimen), Redear (16 specimens), and Blue catfish (2 specimens). The Shannon-Weiner Diversity Index of fish species at C-6 was 2.8 bits per individual.

4.2.7 Site C-7

Site C-7, Grassy Lake, is an intermediate stream/open water site in an area of forested wetland. Based upon the vegetation types and average salinity, it was classified as a mixed salinity site.

The average DO at Site C-7 was below 5 mg/L at 3.8 mg/L in summer 2005. The average DO value increased to 10.1 mg/L in winter 2006, and decreased to 7.7 mg/L in spring 2006. The average DO value dropped to 3.9 mg/L in summer 2006.

The minimum DO values were below 5 mg/L at 1.0 mg /L and 0.9 mg/L in the two summer sampling events, respectively. In winter 2006, the minimum DO value was 7.9 mg/L. The minimum DO value was slightly below 5 mg/L at 4.8 mg/L during spring 2006.

Results of surface water analysis showed that ammonia concentrations ranged from below detection limit (0.05) to 0.15 mg/L. The highest concentration was in summer 2005 and the lowest value was in winter 2006. The BOD5 value was 6 mg/L in winter sampling, and ≤ 5 in all other sampling events. Chlorophyll-*a* ranged from 0.03 to 0.107 mg/L. The highest Nitrate-N was 0.03 mg/L. The highest Nitrite-N value was 0.04 mg/L. TP levels were between 0.16 and 0.48 mg/L. TKN ranged from 1.43 to 1.8 mg/L. TSS was 14 mg/L in summer 2005, 126 mg/L in winter 2006, 33 and 20 mg/L in spring and summer 2006.

Total Organic Carbon (TOC) in sediments was 68,000 mg/kg in summer 2005 and 96,600 mg/kg in spring 2006. In summer 2005, percent total solids was 19.7 percent. In April 2006, percent total solids was 22.21 percent, and sediment particles consisted of 54.59 percent clay, 23.75 percent silt, and 21.66 percent sand.

Habitat assessment was conducted in two summer sampling events at site C-7. In summer 2005, the Site was surrounded by forested wetland. Black willow and *Typha* were the dominant riparian vegetation. There was approximately 10 m^2 large woody debris present. There was no submerged aquatic vegetation. Twenty percent of the sample reach had emergent aquatic vegetation, which was comprised of 10 percent alligatorweed , 5 percent cattails, and 5 percent unknown grass. Total floating vegetation (water hyacinth 35 percent, duckweed 20 percent, and *Salvinia* sp. 35 percent) was present in 80 percent of the sample reach. Coverage occurred near the shorelines. On July 31, 2006, there was approximately 5 m^2 large woody debris presents. There was no submerged aquatic vegetation present. Ten percent of the sample reach had emergent alligatorweed, and 5 percent of the sample reach had emergent cattails. Floating water hyacinth was present in 10 percent of the sample reach. Floating *Salvinia* sp. was present in 20 percent of the sample reach, and duckweed was present in 5 percent of the sample reach.

In summer 2005, there were a total of 10,493 individuals representing 25 species in the Dip net samples collected from site C-7. The Shannon-Weiner diversity was 2.86 bits and density was 3384.68/m^2. The most abundant taxa in Dip net samples were Glyptotendipes, *Hyalella azteca*, and Chironomidae. For the Petite Ponar samples, 329 individuals representing 13 species were collected. The Shannon-Weiner diversity was 1.68 bits and Density was 22.90/m^2. The most abundant taxa in Petite Ponar samples were *Hyalella azteca,* Glyptotendipes and Hirudinea.

In summer 2006, a total of 5,191 individuals representing 32 species in the Dip net samples were collected from site C-7. The Shannon-Weiner diversity was 3.36 bits. For the Petite Ponar samples, 371 individuals representing 32 species were collected. The Shannon-Weiner diversity was 3.31 bits.

The Dip net sample in 2006 had moderate abundance (>5191/sample) and moderate richness (32 taxa) for a vegetation sample. The amphipod, *Hyalella* sp. (39.2 percent) was the most abundant taxa in the sample. *Hyallella* is tolerant to high temperatures of hot springs, high mineral concentrations and salinity. Although not exceptionally tolerant to low DO concentrations, they are tolerant to high temperature, which reduces the solubility of oxygen in water. The chironomid midges, *Parachironomus* sp. (12.6 percent) and *Glyptotendipes* sp. (9.7 percent) were also abundant taxa in the sample.

The Ponar sample had moderate abundance (371/sample) and high richness (32 taxa) for a sediment Ponar grab sample. The chironomid midge *Glyptotendipes* sp. (29.7 percent) was the most-abundant taxon in the sample. *Glyptotendipes* are common among the sediments of very organic slow moving waters. Larvae of some species live in the tissues of aquatic vegetation, upon which they feed. They are also found in benthic mats of algae or among organic deposits among the benthos.

The amphipod, *Hyalella* sp. (24 percent) was the second-most abundant taxon in the sample. The third most abundant taxon was the chironomid midge *Coelotanypus* sp. (10.5 percent). They are found in very slow or stationary waters among fine sediments. Some species are abundant in very eutrophic ponds. They are predatory and feed upon smaller invertebrates.

A total of 122 individuals representing fifteen fish species were collected at Site C-7 in 2006. All of the specimens were primarily freshwater species. Table 4-17 contains a list of finfish collected at Site C-7. Striped mullet and Spotted gar represented the largest number of the specimens with 39 and 51 samples, respectively. Other species included Largemouth bass (4 specimens), Common bluegill (5 specimens), Black crappie (1 specimen), Smallmouth buffalo (8 specimens), Freshwater drum (3 specimens), Skipjack herring (1 specimen), Common carp (1 specimen), Bowfin (2 specimens), Redear (2 specimens), Channel catfish (1 specimen), Ladyfish (2 specimens), and Flathead catfish (1 specimen). The Shannon-Weiner Diversity Index of fish species at C-7 is 2.42 bits per individual.

4.2.8 Site C-8

Site C-8, South Lake Verret, is in an area of forested wetland. It was classified as intermediate canal/open water and mixed salinity.

The average DO at Site C-8 was below 5 mg/L at 4.4 mg/L in summer 2005. The average DO value decreased to 3.9 mg/L in winter 2006, and was 4.0 mg/L in spring 2006. The average DO value increased to 5.0 mg/L in summer 2006.

The minimum DO values were below 5 mg/L at all sampling events. The value was 0.76 mg/L in summer 2005, 2.3 mg/L in winter 2006, 1.4 mg/L in spring 2006, and 1.6 mg/L in summer 2006.

Ammonia-N fluctuated from 0.17 mg/L in summer 2005 to 0.47 mg/L in winter 2006, dropped to 0.09 in the spring, and then increased to 0.21 in summer 2006. BOD5 ranged between 4 to 6 mg/L. The highest chlorophyll-*a* level was obtained in summer 2006 at 0.0801 mg/L. Both Nitrate-N and Nitrite-N were between 0.02 to 0.03 mg/L except nitrate-N in winter 2006 at 0.09 mg/L. TP was very stable in the first three sampling events at approximately 0.25 mg/L, but increased to 0.92 mg/L in summer 2006. TKN levels were approximately 1.5 mg/L until spring 2005, and increased to 2.4 mg/L in summer 2006. TSS was 22 mg/L in summer 2005, 60 mg/L in winter, 36 mg/L in spring, and 78 mg/L in summer 2006.

In April 2006 at site C-8, Total Organic Carbon (TOC) in sediments was 65,700 mg/kg. Percent total solids was 24.55 percent. Sediment particles consisted of 56.22 percent clay, 38.11 percent silt, and 5.68 percent sand.

Habitat assessment was conducted in two summer sampling events at site C-8. In summer 2005, the Site was surrounded by forested wetland. Red maple and Tupelo trees are the dominant riparian vegetation. There was approximately 25 m^2 large woody debris present. Submerged *Hydrilla* sp. was present in 30 percent of the sample reach. Forty five percent of the sample reach had emergent aquatic vegetation, which was comprised of 40 percent alligatorweed and 5 percent unknown grass. Total floating *Salvinia* sp. was present in 25 percent of the sample reach. Coverage occurred near the shorelines downstream and in the center of water body 100 m upstream. On August 2, 2006, there was approximately 10 m^2 large woody debris. Submerged aquatic vegetation was present in 40 percent of the sample reach (15 percent *Hydrilla* sp. and 30 percent other species). Fifteen percent of the sample reach had emergent Alligatorweed. Floating Duckweed was present at 20 percent sample reach.

In summer 2005, there were a total of 3417 individuals representing 32 species in the Dip net samples collected from site C-8. The Shannon-Weiner diversity was3.36 bits and density was 1102.26/m^2. The most abundant taxa in Dip net samples were *Hyalella azteca*, Glyptotendipes, and Caenis. For the Petite Ponar samples, 186 individuals representing 19 species were collected. The Shannon-Weiner diversity was 3.24 bits and density was 12.95/m^2. The most abundant taxa in Petite Ponar samples were Gastropoda, Parachironomus, and Glyptotendipes.

In summer 2006, there were a total of 14,717 individuals representing 10 species in the Dip net samples collected from site C-8. The Shannon-Weiner diversity was 1.22 bits. For the Petite Ponar samples, 239 individuals representing 23 species were collected. The Shannon-Weiner diversity was 3.38 bits.

The Dip net sample in 2006 contained an extremely high number of invertebrates (>14,717 / sample) and a relatively low number of taxa (only 10 taxa). The chironomid midge *Glyptotendipes* sp. (79.5 percent) was the most abundant taxon in the sample. *Glyptotendipes* are common among the sediments of very organic slow moving waters. Larvae of some species live in the tissues of aquatic vegetation, upon which they feed. Although *Glyptotendipes* was dominant in other samples, the abundance in this sample was exceptional — 11,760 individuals. Other abundant taxa in the sample were the amphipod, *Hyalella* sp. (8.2 percent) and *Parachironomus* (4.1 percent).

The Ponar sample contained a moderate abundance of macroinvertebrates (239/sample) and high richness (23 taxa) for a sediment Ponar Grab sample. The Tubificidae was the most abundant (24.3 percent) taxon. Tubificids include many tolerant species including some taxa that are very tolerant to low DO and salinity. They are often the dominant taxa in rich organic environment and in estuaries. The family includes some of the most tolerant worm species known, such as *Limnodrilus* *hoffmeisteri* and *Tubifex tubifex*. The chironomid midge *Glyptotendipes* sp. (18 percent) was the second most-abundant taxon in the sample.

The predacious midges, Ceratopogonidae (14.2 percent), were the third most abundant taxon in the sample. They are often associated with fine sediments (sand or silt). They move through the sediment without constructing permanent burrows and feed on smaller, relatively sessile invertebrates or the eggs of larger taxa.

A total of 129 individuals representing fifteen fish species were collected at Site C-8 in 2006. All of the specimens were primarily freshwater species. Table 4-17 contains a list of finfish collected at Site C-8. Common bluegill and Spotted gar represented the largest number of the specimens with 32 and 39 samples, respectively. Other species included Largemouth bass (8 specimens), Black crappie (13 specimens), Longear sunfish (1 specimen), Freshwater drum (7 specimens), Gizzard shad (14 specimens), Stripped mullet (4 specimens), Common carp (1 specimen), Bowfin (1 specimen), Redear (1 specimen), Flathead catfish (1 specimen), and Bay anchovy (5 specimens). The Shannon-Weiner Diversity Index of fish species at C-8 was 2.9 bits per individual.

4.2.9 Site C-9

Site C-9, Lake Palourde, is an open water site iin a forested wetland area. It is classified as mixed salinity.

The average DO at Site C-9 was above 5 mg/L at all sampling events. The average DO value was 6.1 mg/L in summer 2005. The standard deviation at this sampling event was 2.3 mg/L. The value increased to 9.8 mg/L in winter 2006, and decreased to 7.0 mg/L in spring 2006. The average DO value was 6.3 mg/L with a standard deviation of 2.6 mg/L in summer 2006.

The minimum DO values were below 5 mg/L at 2.5 mg/L and 2.6 mg/L in the two summer sampling events, respectively. In winter 2006, the minimum DO value was 8.8 mg/L. The minimum DO value was 5.2 mg/L in spring 2006.

Ammonia-N was less than 0.17 mg/L in all samples. BOD5 ranged from 4 - 6 mg/L. Chlorophyll-*a* was lowest in spring at around 0.015 mg/L, and highest in the two summers averaging 0.06 mg/L. Nitrate-N and Nitrite-N were between non-detect (< 0.02 mg/L to 0.05 mg/L) except in a duplicate sample (0.27 mg/L) during spring 2006. TP ranged from 0.12 to 0.36 mg/L. TKN ranged from 0.98 to 1.6 mg/L. TSS was 15 mg/L in summer 2005, 141 mg/L (117 mg/L duplicate) in winter 2006, 30 mg/L in spring, and 56 mg/L (11 mg/L duplicate) in summer 2006.

Total Organic Carbon (TOC) in sediments was 10,900 mg/kg in summer 2005 and 25,000 mg/kg in spring 2006. In summer 2005, percent total solids was 53.49 percent. Sediment particles consisted of 71.53 percent sand, 20.33 percent silt, 8.13 percent clay, and < 0.01 percent gravel. In April 2006, percent total solids was 41.43 percent, and sediment particles consisted of 71.81 percent clay, 20.46 percent silt, and 7.73 percent sand.

Habitat assessment was conducted in two summer sampling events at site C-9. In summer 2005, the Site was surrounded by forested wetland. Cypress trees were the dominant riparian vegetation. There was approximately 25 m^2 large woody debris present. Submerged aquatic vegetation was not observed. Ten percent of the sample reach had emergent alligatorweed. Total floating vegetation (water hyacinth 5 percent, duckweed 5 percent, and *Salvinia* sp. 10 percent) was present in 20 percent of the sample reach. Coverage occurred near the right bank. On July 31, 2006, there was approximately 30 m^2 large woody debris. There was no submerged aquatic vegetation. Five percent of the sample reach had emergent alligatorweed. Floating water hyacinth was present in 5 percent of the sample reach. Floating *Salvinia* sp. was present in 10 percent of the sample reach.

In summer 2005, there were a total of 19,310 individuals representing 24 species in the Dip net samples collected from site C-9. The Shannon-Weiner diversity was 1.62 bits and density was 7401.10/m^2. The most abundant taxa in Dip net samples were, *Hyalella azteca*, *Glyptotendipes*, and *Caenis*. For the Petite Ponar samples, 8,812 individuals representing 7 species were collected. The Shannon-Weiner diversity was 0.39 bits and density was 613.32/m^2. By far, the most abundant taxon in Petite Ponar samples was Tubificidae; *Hyalella azteca* and Hydrobiidae were next in abundance but represented minor members of the community.

In summer 2006, there were a total of 2,371 individuals representing 31 species in the Dip net samples collected from site C-9. The Shannon-Weiner diversity was 3.51 bits. For the Petite Ponar samples, 54 individuals representing 9 species were collected. The Shannon-Weiner diversity was 1.05 bits.

The Dip net sample in 2006 had moderate invertebrate abundance (2,371/ sample) and moderate richness (31). The most abundant taxon in the sample was the chironomid midge *Glyptotendipes* sp. (32.4 percent). The Naidid oligochaete worms, *Dero* sp. (15.8 percent) and *Pristina leidyi* (14.2 percent), were also abundant taxa in the sample.

The Ponar sample had low abundance (54/sample) for a Ponar grab and low richness (9 taxa). The most abundant taxon was the oligochaete worm *Limnodrilus cervix* (85.2 percent). This worm has been collected throughout North America, even in caves. Like *Limnodrilus hoffmeisteri*, they are tolerant to low DO concentrations, and a wide variety of stressors. Their tolerance to organic chemicals, including pesticides, makes them important agents of ecosystem recovery because their activities may purge sediments of chemicals. The remaining taxa were only represented by 1 individual specimen.

A total of 119 individuals representing eight fish species were collected at Site C-9 in 2006. All of the specimens were primarily freshwater species. Table 4-17 contains a list of finfish collected at Site C-9. Striped mullet represented the largest number of the specimens with 66 samples. Other species included Common bluegill (1 specimen), Gizzard shad (28 specimens), Skipjack herring (1 specimen), American Eel (2 specimens), Spotted gar (17 specimens), Bowfin (2 specimens), and Channel catfish (2 specimens). The Shannon-Weiner Diversity Index of fish species at C-9 was 1.78 bits per individual

4.2.10 Site C-10

Site C-10 is a large slough in Bay Wallace. It is shallow in the upper reaches with exceptional habitat. It is a contiguous cypress swamp, classified for this study as small stream/bay and mixed salinity.

The average DO at Site C-10 was 8.7 mg/L with a standard deviation of 1.8 mg/L in summer 2005. The average DO value decreased to 7.4 mg/L in winter 2006, and continuously decreased to 6.2 mg/L in spring 2006, and 3.2 mg/L in summer 2006.

The minimum DO value was slightly below 5 mg/L at 4.9 mg/L in summer 2005. The minimum value was 5.2 mg/L in winter 2006, 3.4 mg/L in spring 2006, and 0.84 mg/L in summer 2006.

Ammonia-N ranged from below detection limit to 0.10 mg/L. BOD5 values were 3 and 4 mg/L in summer 2005 and winter 2006 and below detection limit in spring and summer 2006. Chlorophyll-*a* was highest in winter at 0.0694 mg/L. Nitrate-N was relatively high in winter and spring at around 0.16 mg/L. Nitrite-N was no higher than 0.3 mg/L in all samples. TP and TKN were very stable and averaged at 0.14 mg/L and 10 mg/L, respectively. TSS was 8 mg/L in summer 2005, increased to 38 mg/L in winter 2006, and dropped to 16 and 11 mg/L in spring and summer 2006.

Total Organic Carbon (TOC) in sediments was 400,000 mg/kg in summer 2005 and 283,000 mg/kg in spring 2006. In summer 2005, percent total solids was 9.3 percent. In April 2006, percent total solids was 6.92 percent.

Habitat assessment was conducted in two summer sampling events at site C-10. In summer 2005, the Site was surrounded by forested wetland. Cypress trees were the dominant riparian vegetation. There was no large woody debris present. Submerged aquatic *Elodea* sp. and watermilfoil were both present in 2 percent of the sample reach. Twelve percent of the sample reach had emergent alligatorweed. Total floating vegetation (water hyacinth 9 percent, duckweed 50 percent, and *Salvinia* sp. 25 percent) was present in 84 percent of the sample reach. The water of the entire upper stream was covered with floating vegetation. On July 31, 2006, there was approximately 4 m^2 large woody debris. There was 10 percent submerged aquatic vegetation. Ten percent of the sample reach had emergent alligatorweed. Floating water hyacinth was present in 15 percent of the sample reach and floating *Salvinia* sp. was present in 20 percent of the sample reach.

In summer 2005, there was a total of 2,576 individuals representing 23 species in the Dip net samples collected from site C-10. The Shannon-Weiner diversity was3.36 bits and density was 830.97/m^2. The most abundant taxa in Dip net samples were *Hyalella azteca*, Physella, and *Palaemonetes kadiakensis*. For the Petite Ponar samples, 2,163 individuals representing 3 species were collected. The Shannon-Weiner diversity was 0.25 bits and density was 150.54/m^2. By far, the most abundant taxon in Petite Ponar samples was Tubificidae; Ceratopogonidae and *Helobdella stagnalis* were next in abundance but represented minor members of the community.

In summer 2006, there were a total of 4,718 individuals representing 39 species in the Dip net samples collected from site C-10. The Shannon-Weiner diversity was 4.28 bits. For the Petite

Ponar samples, 32 individuals representing 14 species were collected. The Shannon-Weiner diversity was 3.44 bits.

The Dip net sample in 2006 had moderate abundance (4,718 /sample) for a vegetation sample and high richness (39 taxa). The chironomid midge, *Parachironomus* sp. (17.5 percent) was the most abundant taxon in the sample. The amphipod, *Hyalella* sp. (15.1 percent) was also abundant in the sample.

The snail *Physa* sp. (9.5 percent) was the third most abundant taxon. *Physa* occurs in a wide variety of streams, rivers, lakes, wetlands, and estuaries. However, in flowing ecosystems, it is usually located in sediment-laden back waters. It is behavior-adapted to low DO concentrations, which cause it to visit the water surface or actually leave the water briefly. By staying moist, they can breathe atmospheric oxygen. If there is no substrate to allow escape from the water, they can use vegetation and glide along the underside of the water's surface film. They are omnivorous, scraping plant material, detritus, or scavenging larger organic particles.

The Ponar sample had low abundance for a Ponar grab sample (32/sample) and moderate richness (14 taxa). Because of the low abundance of the sample, even the dominant taxa were not very abundant (4-6 individuals).

The caenid mayfly *Caenis diminuta* (18.8 percent) was an abundant taxon in the sample. Mayflies often indicate clear cold waters with high DO concentrations. However, the caenids are an exception and can be found in warmer waters with lower oxygen concentrations. Their gills are highly branched and very effective at gas exchange. The anterior gills are modified to form an operculum that covers and protects the delicate functional gills from abrasion by sediment. Although sediment tolerant, they require stable substrata to cling to and are ineffective burrowers. Their dominance in this sample may be related to the habitat provided by the vegetation.

The amphipod *Gammarus* sp. (18.8 percent) was also an abundant taxon in the sample. *Gammarus* is found in a wide variety of standing and flowing aquatic habitats. They are often found near deposits of fine organic matter upon which they feed. They are tolerant to a variety stressors and may be found in urban aquatic habitats. The chironomid midge, *Parachironomus* sp. (12.5 percent) was also an abundant taxon in the sample.

A total of 126 individuals representing eleven fish species were collected at Site C-10. All of the specimens were primarily freshwater species. Table 4-17 contains a list of finfish collected at Site C-10. Spotted Gar represented the largest number of the specimens with 57 samples. Other species included Largemouth bass (13 specimens), Common bluegill (10 specimens), Gizzard shad (28 specimens), Striped mullet (5 specimens), Skipjack herring (1 specimen), Black crappie (3 specimens), Bowfin (2 specimens), Channel catfish (4 specimens), Blue catfish (2 specimens), and Golden shiner (1 specimen). The Shannon-Weiner Diversity Index of fish species at C-10 was 2.4 bits per individual.

4.2.11 Site C-11

Site C-11, Bayou Tambour, is a saline site in an intermediate stream.

The average DO at Site C-11 was above 4 mg/L at all sampling events. The average DO value was 7.8 mg/L in summer 2005, 8.9 mg/L in winter 2006, 6.7 mg/L in spring 2006, and 5.3 mg/L in summer 2006.

The minimum DO values were above 4 mg/L during summer 2005, winter 2006, and spring 2006. In summer 2006, the minimum DO value was 3.0 mg/L.

Ammonia was only detected in winter and spring at 0.18 and 0.06 mg/L, respectively. BOD5 was not analyzed in summer 2005, and its highest level was 4 mg/L in summer 2006. Chlorophyll-*a* ranged between < 0.010 to 0.0267 mg/L. Nitrate-N and Nitrite-N were no higher than 0.02 mg/L in all samples except in winter at 0.16 mg/L. TP ranged between 0.09 and 0.17 mg/L. TKN was between 1.47 and 2.63 mg/L. TSS was 18 mg/L in summer 2005, 115 mg/L in winter, 48 mg/L in the spring, and 36 mg/L in summer 2006.

In August 2006 at site C-11, Total Organic Carbon (TOC) in sediments was 102,000 mg/kg. Percent total solids was 18.75 percent. Sediment particles consisted of 53.95 percent clay, 43.24 percent silt, and 2.81 percent sand.

Habitat assessment was conducted in summer 2006 at C-11. On August 7, 2006, the area was surrounded by non-forested wetland. Grasses were the dominant riparian vegetation. There was no large woody debris. Emergent aquatic vegetation was present in 100 percent of the sample reach (20 percent *Spartina alterniflora* and 80 percent *Juncus romerianus*). There was no submerged and floating aquatic vegetation.

There were a total of 147 individuals representing 18 species in the Dip net samples collected from site C-11 in 2006. Therefore, this sample would be considered to have moderate abundance and richness. The Shannon-Weiner diversity was 3.60 bits. For the Petite Ponar samples, 5 individuals representing 3 species were collected reflecting low abundance and richness. The Shannon-Weiner diversity was 1.37 bits.

In the Dip net sample, the grass shrimp, *Palaemonetes pugio* (15.7 percent) was the single most abundant taxon in the sample. The ecological importance of this species in tidal marshes was detailed by Welsh (1975), who found that they facilitate nutrient cycling and primary production. They facilitated transfer of energy to different trophic levels through physically altering detritus, releasing dissolved organic mater, stimulating algal growth, bioturbation, and as prey. This species is adapted to low-oxygen environments and has a wide range of tolerance for salinity and temperature. This allows the species to achieve very high abundances free from the pressures of predation and competition. Leigh et al. (2005) found that better agricultural practices in adjacent lands resulted in greater abundances of *P. pugio*.

The second most abundant taxon was the marine amphipod *Apocorophium louisianum* (14.9 percent). Much of the ecological information for this species was summarized while this taxon was considered to be part of another genus. The species is abundant in gulf-coast marine habitats and has been also introduced to the Salton Sea, a saline, Californian lake. The species is usually found in brackish water exhibiting salinity up to 75 ppm. They build tubes on the bases of aquatic vegetation and are an important food of marine fishes.

The third most abundant taxon in the sample is the tanaidacean, *Hargeria rapax* (12.9 percent). The Tanaidacea are poorly known but represent an important crustacean group nonetheless. Interestingly, some studies on the Georgia coast have shown that the omnivorous grass shrimp (*P. pugio*; above) can feed on *Hargeria* sufficiently to reduce their abundance. In a survey of *H. rapax* population dynamics, thousands per m^2 were collected, with greatest abundance in the high-tidal marsh. Reproductive stages were collected all year but peaked in autumn (late August – November) and spring (March- early June).

In the Ponar sample, there were only five invertebrate organisms in the sample represented by three taxa. Thus, this sample was characterized by extremely low abundance and richness. Generally, systems are healthier when they support higher densities and diversity.

By far the single most abundant taxon in this sediment sample was the marine amphipod *Ampelisca* sp. (60 percent, 3 individuals). Amphipods are usually collector-gatherers and are often found in great abundances in aquatic vegetation. In a study comparing the invertebrate fauna of natural marine vegetation and artificial sand beds off the coast of Portugal, researchers found that although the vegetation supported greater density, richness, and diversity of amphipods, the genus *Ampelisca* was dominant in both habitats (different species). Other studies have shown that although *Ampelisca* is sensitive to industrial sediment contamination (Gulf coast, Louisiana), that they were tolerant to reduced interstitial salinity.

Cerapus cudjoe was described in 1991 from the Florida Keys, where it was associated with strong tidal flows and marine vegetation. This amphipod comprised about 20 percent of the sample (1 individual). Since males are active movers during slack tides, the individual may be an errant collection.

An immature member of family Leptocheliidae (20 percent; 1 individual) was also in the sample. Since *Hargeria* is also a tanaidacean in the family, the specimen in this sample may be an immature *Hargeria*.

A total of 162 individuals representing nine fish species were collected at Site C-11 in 2006. All of the specimens were primarily saltwater species. Table 4-18 contains a list of finfish collected at Site C-11. Atlantic croaker represented the largest number of specimens with 93 samples. Other species included Bay anchovy (28 specimens), Hardhead catfish (1 specimen), Gafftopsail catfish (2 specimens), Gulf toadfish (1 specimen), Pinfish (7 specimens), Speckled trout (1 specimen), Spadefish (26 specimens), and Least pufferfish (3 specimens). The Shannon-Weiner Diversity Index of fish species at C-11 was 1.84 bits per individual.

4.2.12 Site C-12

Site C-12, Jude's Cut, is a saline site classified as an intermediate stream. It is in a non-forested wetland area.

DO data in summer 2005 were anomalous and indicative of a sonde malfunction. The average DO values were 7.4 mg/L and 7.2 mg/L in winter and spring 2006, respectively. The average value decreased to 5.5 mg/L in summer 2006.

The minimum DO value was below 4 mg/L at 3.0 mg/L in the summer 2006. In winter and spring 2006, the minimum DO value was 5.9 mg/L.

Ammonia as N was only detected in winter and spring at 0.09 mg/L. BOD5 was 3 mg/L in spring and summer 2006. Chlorophyll-*a* ranged between <0.010 to 0.0222 mg/L. Nitrate-N was only detected at 0.02 mg/L during winter 2006. Nitrite-N was only detected in summer 2005 at 0.02 mg/L. TP was very stable at approximately 0.15 mg/L in all samples. TKN was between 0.9 to 2.11 mg/L. TSS was 44 mg/L in summer 2005, 33 mg/L in winter 2006, 94 mg/L in spring, and 83 mg/L in summer 2006.

In August 2006 at site C-12, Total Organic Carbon (TOC) in sediments was 39,400 mg/kg. Percent total solids was 40.93 percent. Sediment particles consisted of 46.54 percent sand, 29.7 percent silt, and 23.76 percent clay.

Habitat assessment was conducted in summer 2006 at C-12. On August 2, 2006, the area was surrounded by non-forested wetland. Grasses were the dominant riparian vegetation. There was no large woody debris observed. Emergent aquatic vegetation was present in 100 percent of the sample reach (25 percent *Spartina alterniflora* and 75 percent *Juncus romerianus*). There was no submerged and floating aquatic vegetation.

In 2006, there were a total of 86 individuals representing 18 species in the Dip net samples collected from site C-12. The Shannon-Weiner diversity was 3.11 bits. For the Petite Ponar samples, 55 individuals representing 17 species were collected. The Shannon-Weiner diversity was 3.50 bits.

The Dip net sample contained 86 invertebrates, among 18 taxa. Thus abundance and richness is moderate for this sample. The single most abundant taxon was the common periwinkle, *Littorina* sp. (39.5 percent), an inter-tidal snail. This taxon can be a dominant grazer in estuary systems and when present can reduce the biomass of *Spartina* grasses significantly. It also has been speculated to be a strong competitor with arthropod grazers, which have shown reduced abundance when *Littorina* abundances are high. A study of salinity and desiccation tolerance of two *Littorina* populations (1 collected from metals effluents) found that metals tolerance may have made one population more susceptible to desiccation.

Oligochaete worms, like Enchytraeidae (15.1 percent) are most often associated with sediments, algae, or vascular plants. They generally feed on fine detritus, but may also ingest rotifers or algae.

Immature crabs (Brachyura) comprised the third most abundant taxon (8.1 percent) in the sample. Crabs are opportunistic omnivores that may consume marine vegetation, animal matter or detritus.

The Ponar sample contained 55 invertebrates, among 17 taxa. Thus the abundance and richness is moderate for this habitat. Insects are usually absent from marine benthos, but this sample contained one taxon, the midge *Tanypus* sp., represented by one individual. *Tanypus* is a predatory chironomid midge tolerant of elevated salinity levels.

The dominant taxon in the sample was the Oligochaete worm family Enchytraeidae (25.4 percent). They are most often associated with sediments, algae, or vascular plants, and generally feed on fine detritus, but may also ingest rotifers or algae. The other abundant taxa were the common periwinkle (12.7 percent), *Littorina* sp., and immature bivalves (12.7 percent). Bivalves are generally infaunal benthic residents that make a living by filtering fine particles of detritus from the water column. In marine environments they generally become less abundant and less diverse at greater depths.

A total of 1,133 individuals representing twenty fish species were collected at Site C-12 in 2006. All of the specimens were primarily saltwater species. Table 4-18 contains a list of finfish collected at Site C-12. Bay anchovy represented the largest number of the specimens with 1,022 samples. Other species included Southern stingray (3 specimens), Ladyfish (2 specimens), Gulf Menhaden (1 specimen), Hardhead catfish (16 specimens), Gafftopsail catfish (27 specimens), Gulf toadfish (3 specimens), Chain pipefish (1 specimen), Look down (1 specimen), Sheepshead (1 specimen), Pinfish (12 specimens), Speckled trout (1 specimen), Spot (2 specimens), Atlantic croaker (19 specimens), Spadefish (10 specimens), Violet goby (1 specimen), Bay whiff (4 specimens), Southern flounder (1 specimen), Blackcheek tonguefish (2 specimens), and Least pufferfish (4 specimens). The Shannon-Weiner Diversity Index of fish species at C-12 was 0.79 bits per individual.

4.2.13 Site C-13

Site C-13, Bayou Platt, is a saline site classified as an intermediate stream. It is in a non-forested wetland area.

The average DO at Site C-13 was above 4 mg/L during all sampling events. The average DO value was 7.2 mg/L in summer 2005, 7.3 mg/L in winter 2006, and 6.2 mg/L in spring 2006. In summer 2006, the average DO value was 4.8 mg/L with a standard deviation of 2.0 mg/L.

The minimum DO values were below 4 mg/L during the two summer sampling events. The minimum DO value was 3.0 mg/L in summer 2005, 5.7 mg/L in winter 2006, 4.1 mg/L in spring 2005, and 1.6 mg/L in summer 2006.

Surface water sampling results showed that ammonia as N was 0.11 mg/L in summer 2006, 0.31 mg/L in winter, 0.09 mg/L in spring, and was not detected in summer 2006. BOD5 levels were at 3 mg/L in all sampling events. Chlorophyll-*a* was highest in summer 2006 at 0.0267 mg/L. Nitrate-N and Nitrite-N were only detected in winter at 0.13 and 0.03 mg/L, respectively. TP was between

0.08 to 0.18 mg/L. TKN was stable and averaged at around 1.7 mg/L. TSS was 20 mg/L in summer 2005, 26 mg/L in winter, 66 mg/L in spring, and 54 mg/L in summer 2006.

In August 2006 at site C-13, Total Organic Carbon (TOC) in sediments was 166,000 mg/kg. Percent total solids was 14.24 percent. Sediment particles consisted of 47.08 percent clay, 44.74 percent silt, and 8.18 percent sand.

Habitat assessment was conducted in summer 2006 at C-13. On August 9, 2006, the area was surrounded by non-forested wetland. Grasses were the dominant riparian vegetation. There was no large woody debris. Emergent aquatic vegetation was present in 100 percent of the sample reach (20 percent *Spartina patens*, 20 percent *Spartina alterniflora*, and 60 percent *Juncus romerianus*). There was no submerged and floating aquatic vegetation.

In 2006, there were a total of 285 individuals representing 18 species in the Dip net samples collected from site C-13. The Shannon-Weiner diversity was 2.32 bits. For the Petite Ponar samples, 11 individuals representing 4 species were collected. The Shannon-Weiner diversity was 1.44 bits.

The Dip net sample contained 285 invertebrates, and 18 taxa. Thus the abundance is high and richness is moderate. The grass shrimp, *Palaemonetes pugio* (42.5 percent) was the single most abundant taxon in the sample. Mud snails, Hydrobiidae, comprised the second most abundant taxon in the sample (33 percent).

The marine isopod, *Sphaeroma* sp. (8.8 percent) was the third most abundant taxon in the sample. Some species are wood borers in mangroves, while others burrow into sediments. They are generally shedder-detritivores and eat decaying vegetation. Adults of some species have some osmoregulatory abilities and may be able to survive low salinities for extended periods.

The Ponar sample consisted of low abundance (11 individuals) and richness (only 4 taxa). The dominant taxon was the predatory chironomid midge, *Tanypus* sp. (6 individuals; 54.6 percent). *Tanypus* is a predatory chironomid midge tolerant to elevated salinity levels.

The second most abundant taxon was the class Polychaeta (3 individuals, 27.3 percent). Polychaeta are often filter-feeders or sometimes predators. Many species burrow into sediments and construct tubes from which they feed on suspended detritus and plankton.

Immature tubificid worms (2 individuals, 18.2 percent) were the third taxon in the sample. Tubificids are usually burrowers with a wide range of tolerance to stressors. They usually consume fine particles of benthic detritus.

A total of 1,161 individuals representing seventeen fish species were collected at Site C-13 in 2006. All of the specimens were primarily saltwater species. Table 4-18 contains a list of finfish collected at Site C-13. Bay anchovy represented the largest number of the specimens with 1,063 samples. Other species included Bull shark (4 specimens), Hardhead catfish (8 specimens), Gafftopsail catfish (3 specimens), Gulf toadfish (1 specimen), Sheepshead (2 specimens), Pinfish

(34 specimens), Sliver perch (3 specimens), Sand seatrout (1 specimen), Speckled trout (1 specimen), Unknown seatrout (16 specimens), Spot (7 specimens), Atlantic croaker (9 specimens), Spadefish (6 specimens), Stripped blenny (1 specimen), Violet goby (1 specimen), and Spanish mackerel (1 specimen). The Shannon-Weiner Diversity Index of fish species at C-13 was 0.68 bits per individual.

4.2.14 Site C-14

Site C-14, Fred Bayou, is in a non-forested wetland area. It is classified as an intermediate stream and saline.

The average DO at Site C-14 was above 4 mg/L at all sampling events. The average DO value was 8.6 mg/L in summer 2005, 9.5 mg/L in winter 2006, 6.7 mg/L in spring 2006, and 6.8 mg/L in summer 2006.

The minimum DO values were above 4 mg/L in the first three sampling events. In summer 2006, the minimum DO value was 3.1 mg/L.

Ammonia as N was less than 0.06 mg/L in all sampling events. BOD5 was between 3 to 5 mg/L. Chlorophyll-*a* ranged from 0.0101 to 0.0312 mg/L. Nitrate-N was only detected in summer 2006 at 0.04 mg /L, and Nitrite-N was only detected in spring at 0.02 mg/L. TP ranged from 0.11 to 0.19 mg/L. The lowest level of TKN was 1.41 mg/L in winter; the highest concentration was 2.03 mg/L in spring. TSS was 24 mg/L in summer 2005, 30 mg/L in winter, 187 mg/L in spring, and 44 mg/L in summer 2006.

In August 2006 at site C-14, Total Organic Carbon (TOC) in sediments was 79,700 mg/kg. Percent total solids was 22.57 percent. Sediment particles consisted of 37.92 percent silt, 36.32 percent clay, and 25.76 percent sand.

Habitat assessment was conducted in summer 2006 at C-14. On August 8, 2006, the area was surrounded by non-forested wetland. Grasses and herbaceous vegetation were the dominant riparian vegetation. There was no large woody debris. Emergent aquatic vegetation was present in 100 percent of the sample reach (30 percent *Spartina alterniflora* and 70 percent *Juncus romerianus*). There was no submerged and floating aquatic vegetation.

In 2006, 152 individuals representing 14 species in the Dip net samples collected from site C-14. The Shannon-Weiner diversity was 2.48 bits. For the Petite Ponar samples, 7 individuals representing 4 species were collected. The Shannon-Weiner diversity was 1.66 bits.

The Dip net sample consisted of moderate abundance (152 individuals) and richness (14 taxa). Although insects are usually absent from marine samples, two genera of Chironomidae midges (*Pseudosmitia* sp., *Dicrotendipes* sp.) occurred in the sample in very low abundances. Both are known to have larvae with an affinity for saline waters. Mud snails, Hydrobiidae, comprised the single most abundant taxon in the sample (52 percent). The grass shrimp, *Palaemonetes pugio*

(11.2 percent) was the next most abundant taxon in the sample. The marine isopod, *Sphaeroma* sp. (10.5 percent), was the third most abundant taxon in the sample.

The Ponar sample consisted of low abundance (7 individuals) and richness (4 taxa). Although insects are usually absent from marine samples, two genera of Chironomidae midges (*Chironomus* sp., *Tanypus* sp.) occurred in the sample in very low abundances. Both are known to have larvae with an affinity for saline waters. *Chironomus* (14.3 percent) is particularly tolerant to periodic anaerobic conditions. *Tanypus* (57.1 percent) is predatory midge that is also tolerant to low oxygen concentrations, and elevated nutrient and salinity levels.

Three taxa were only represented by 1 specimen in the sample (*Chironomus* sp., Hydrobiidae, and *P. pugio*). One individual is equivalent to 14.3 percent of the organisms in this low-abundance sample. Mud snails (Hydrobiidae; 14.3 percent) may benefit from nutrient enrichment.

A total of 825 individuals representing twelve fish species were collected at Site C-14 in 2006. All of the specimens were primarily saltwater species. Table 4-18 contains a list of finfish collected at Site C-14. Bay anchovy represented the largest number of the specimens with 758 samples. Other species included Bull shark (2 specimens), Southern stingray (1 specimen), Gafftopsail catfish (16 specimens), Silver perch (1 specimen), Sand seatrout (6 specimens), Unknown seatrout (2 specimens), Atlantic croaker (25 specimens), Black drum (1 specimen), Red drum (1 specimen), Violet goby (1 specimen), and Least pufferfish (11 specimens). The Shannon-Weiner Diversity Index of fish species at C-14 was 0.61 bits per individual.

4.2.15 Site C-15

Site C-15 is a saline site classified as a large stream. It is in a non-forested area.

The average DO at Site C-15 was above 4 mg/L at all sampling events. The highest average DO value was observed in summer 2005 at 11.9 mg/L with a standard deviation of 4.8 mg/L. The values decreased to 8.8 mg/L in winter 2006, 6.5 mg/L in spring 2006, and 5.5 mg/L in summer 2006.

The minimum DO values were below 4 mg/L during the two summer sampling events. In summer 2005, the lowest DO value was at 2.3 mg /L and 3.4 mg/L in summer 2006. In spring 2006, the minimum DO value was 4.0 mg/L. The minimum DO value was 7.2 mg/L in winter 2006.

Ammonia as N was only detected in winter at 0.4 mg/L and in spring at 0.1 mg/L. BOD5 ranged from 3 to 4 mg/L. Chlorophyll-*a* ranged from 0.015 to 0.0534 mg/L. Nitrate-N was only detected in winter at 0.12 mg/L. Nitrite-N was 0.03 mg/L in summer 2005, 0.04 mg/L in winter, and below detection limit in spring and summer 2006. TP averaged 0.17 mg/L. TKN averaged 1.6 mg/L. TSS was 44 mg/L in summer 2005, 48 mg/L in winter, 35 mg/L in spring, and 70 mg/L in summer 2006.

In August 2006 at site C-15, Total Organic Carbon (TOC) in sediments was 66,000 mg/kg. Percent total solids was 26.18 percent. Sediment particles consisted of 43.58 percent clay, 37.29 percent silt, and 19.13 percent sand.

Habitat assessment was conducted in summer 2006 at C-15. On August 8, 2006, the area was surrounded by non-forested wetland. Grasses were the dominant riparian vegetation. There was no large woody debris. Emergent aquatic vegetation was present in 100 percent sample reach (5 percent *Spartina patens*, 20 percent *Spartina alterniflora*, and 75 percent *Juncus romerianus*). There was no submerged and floating aquatic vegetation.

In 2006, there were a total of 49 individuals representing 14 species in the Dip net samples collected from site C-15. The Shannon-Weiner diversity was 2.89 bits. For the Petite Ponar samples, 2 individuals representing 2 species were collected. The Shannon-Weiner diversity was 1.00 bits.

The Dip net sample had low invertebrate abundance (49 individuals) and low richness (14 taxa). Mud snails, Hydrobiidae, comprised the single most abundant taxon in the sample (36.7 percent). The kelp flies—or seaweed flies—of the family Coelopidae (24.5 percent) were the second most abundant taxon in the sample. These flies are found in or near rotting aquatic vegetation upon which they feed. They can often complete three generations in a year and are rapid colonizers.

The chironomid midge *Dicrotendipes lobus* (6.1 percent) was also abundant in the sample. This species is typically found in estuaries and salt marshes and may be associated with sediments or aquatic vegetation. The common periwinkle, *Littorina* sp., was also abundant (6.1 percent). This taxon can be a dominant grazer in estuary systems and when present can reduce the vegetative biomass significantly.

The Ponar sample was a very unusual sample containing only two invertebrates. Field notes were examined to determine if any unusual events occurred during sample collection. Based on the field sheet, benthic invertebrates were considered abundant. Therefore, it might be possible that the sample was not completely preserved in the field before shipment to the laboratory.

One specimen was a kelp fly—or seaweed fly—of the family Coelopidae. The other specimen was the long-legged fly Dolichopodidae. Like the Coelopidae, the Dolichopodidae are usually collected in marginal habitats and decaying vegetation.

A total of 104 individuals representing eleven fish species were collected at Site C-15 in 2006. All of the specimens were primarily saltwater species. Table 4-18 contains a list of finfish collected at Site C-15. Bay anchovy represented the largest number of the specimens with 54 samples. Other species included Hardhead catfish (14 specimens), Gafftopsail catfish (5 specimens), Gulf toadfish (2 specimens), Sheepshead (2 specimens), Pinfish (4 specimens), Speckled trout (1 specimen), Spot (2 specimens), Atlantic croaker (12 specimens), Spadefish (6 specimens), and Least pufferfish (2 specimens). The Shannon-Weiner Diversity Index of fish species at C-15 was 2.37 bits per individual.

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5. Discussion and Conclusions

5.1 Freshwater and Mixed Sites C-1 through C-10

Based on similarity in salinity, vegetation, and observed biological communities, freshwater sites (C-1 through C-5) and mixed sites (C-6 through C-10) were combined for discussion and presentation. However, mixed sites (C-6 through C-10) are subject to periodic increases in salinity and would be characterized as tidally influenced sites.

5.1.1 Dissolved Oxygen

Average DO at each location is presented in Figure 5-1 through 5-10. The error bars indicate the standard deviation. The DO standard (5 mg/L) is indicated for comparison. Based on attainment of the 5 mg/L DO standard, average DO excursions occurred primarily in summer 2005 and 2006. No average DO excursions occurred during any season at C-9; only a spring 2006 excursion occurred at C-1; and summer 2005, winter 2006, and spring 2006 excursions occurred at C-8.

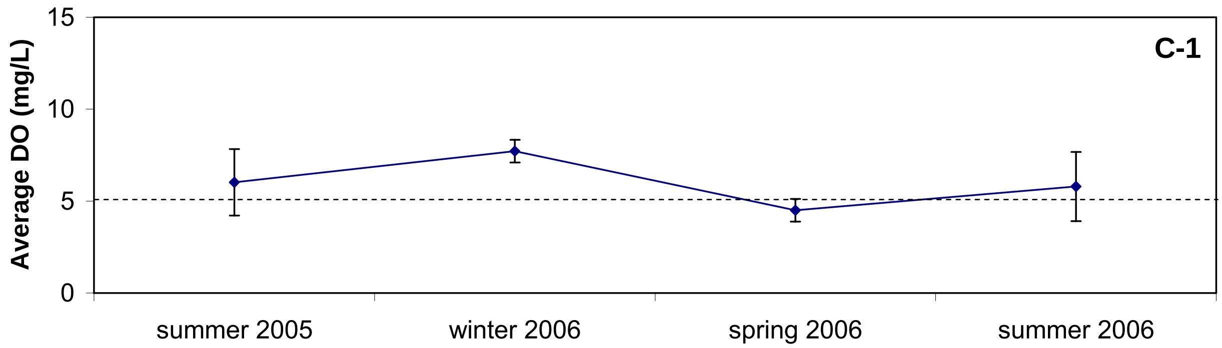

Figure 5-1. Average DO at Location C-1

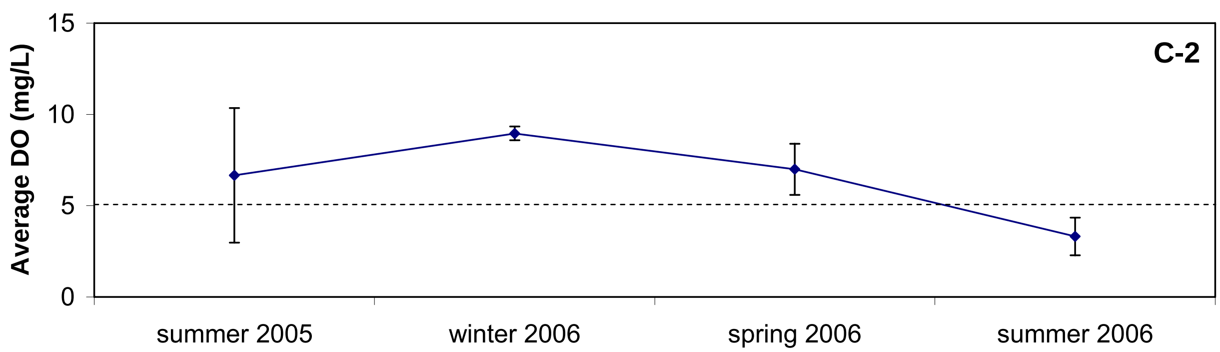

Figure 5-2. Average DO at Location C-2

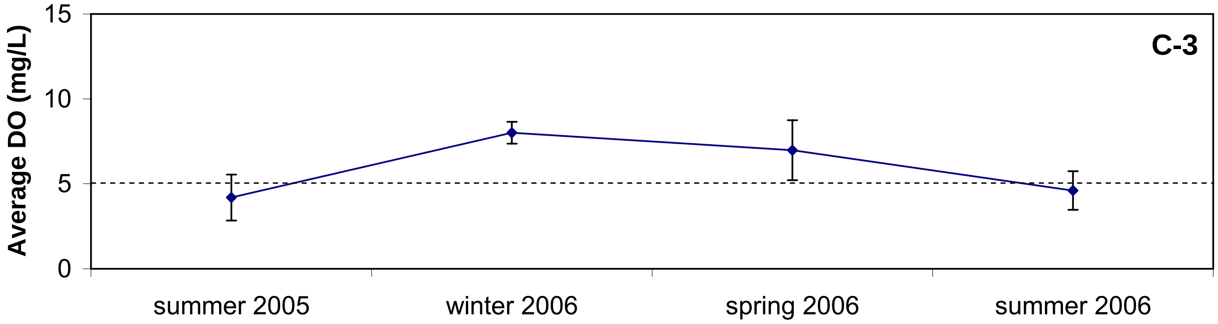

Figure 5-3. Average DO at Location C-3

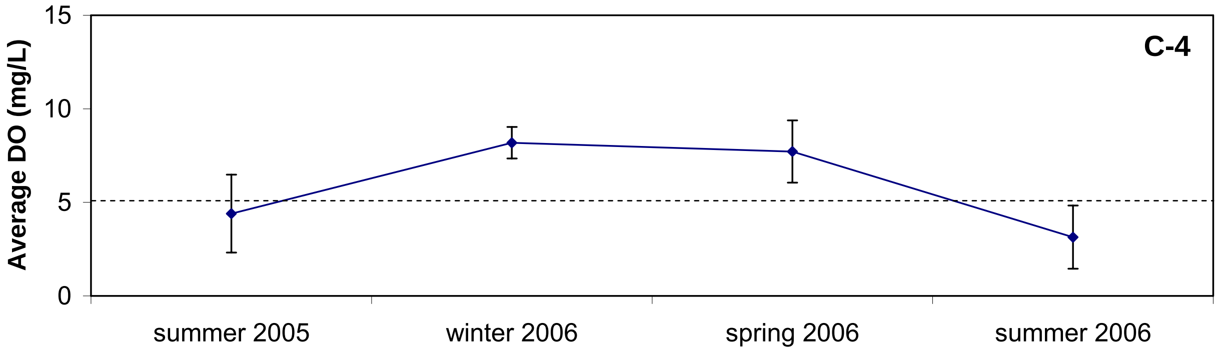

Figure 5-4. Average DO at Location C-4

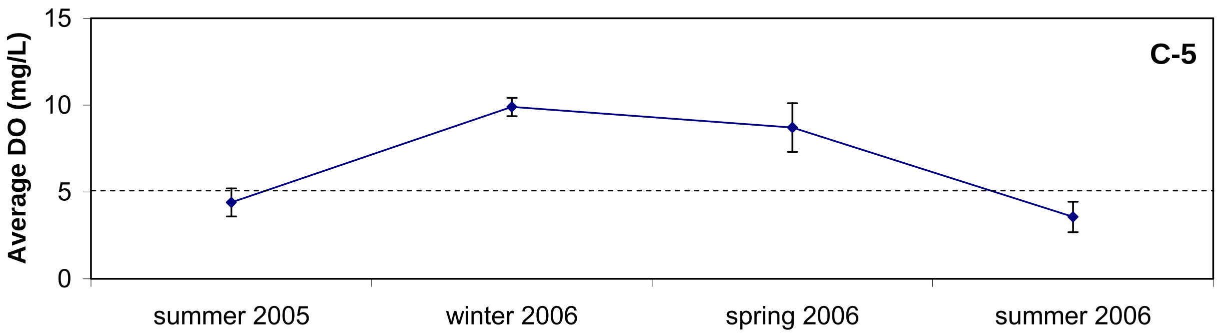

Figure 5-5. Average DO at Location C-5

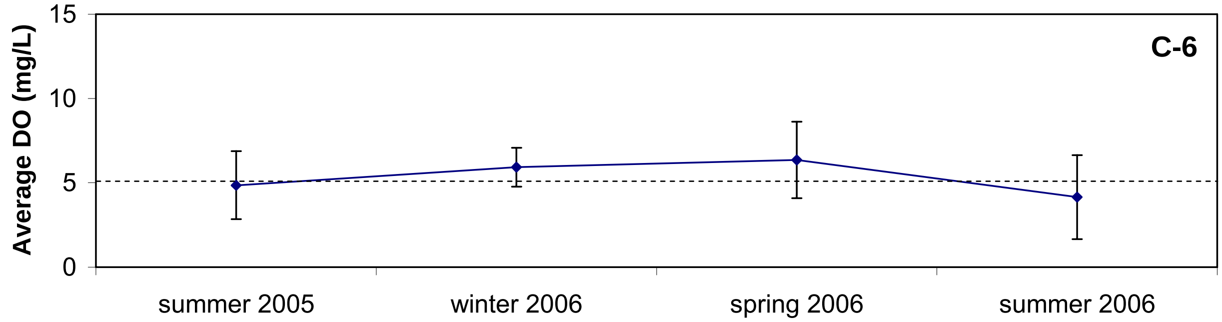

Figure 5-6. Average DO at Location C-6

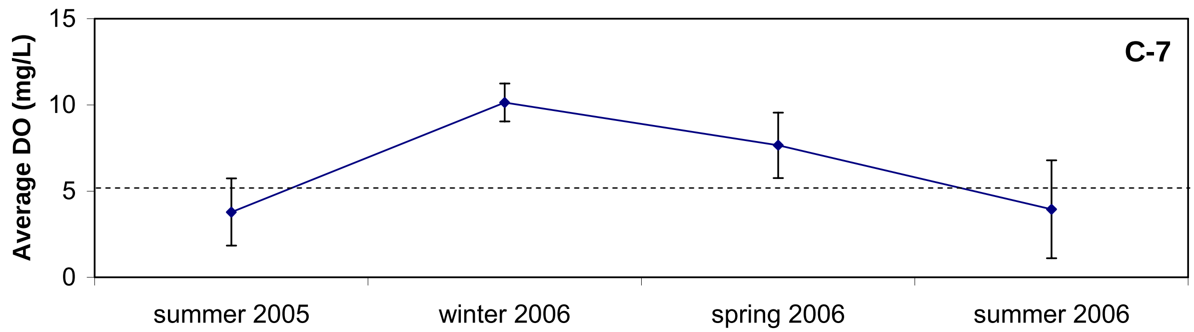

Figure 5-7. Average DO at Location C-7

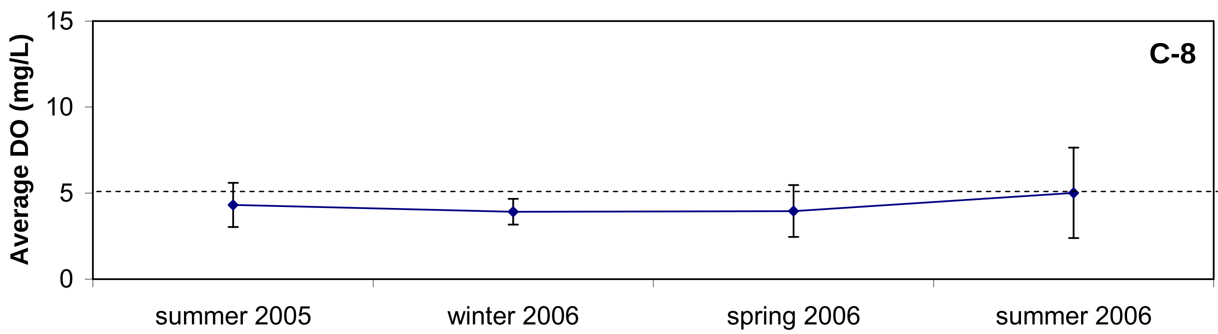

Figure 5-8. Average DO at Location C-8

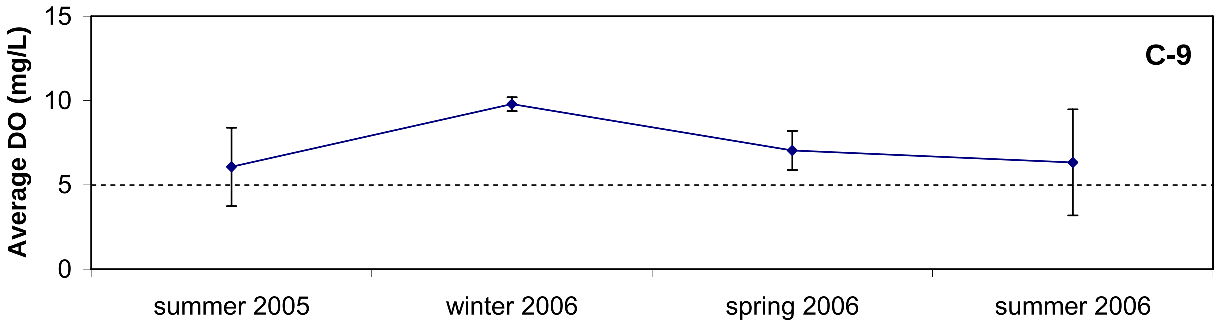

Figure 5-9. Average DO at Location C-9

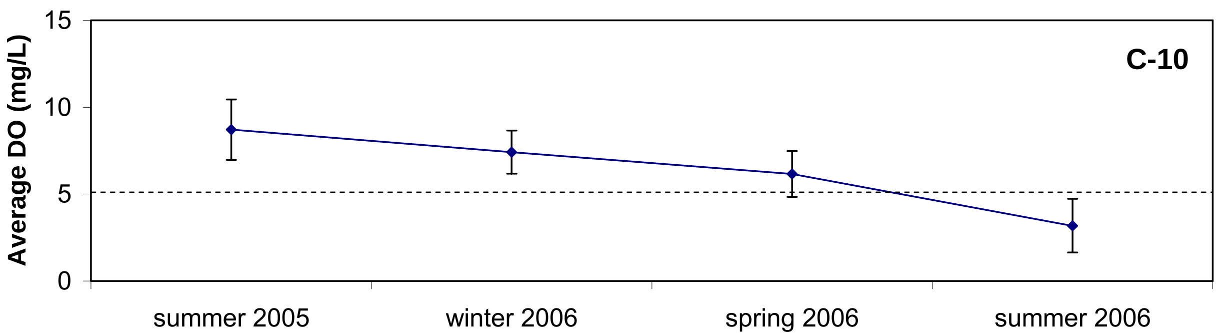

Figure 5-10. Average DO at Location C-10

Excursions of minimum DO also occurred primarily in summer 2005 and 2006 (Figures 5-11 through 5-20). However, more excursions were observed during the spring 2006 and two winter season excursions occurred at C-6 and C-8. Excursions occurred during every season at C-6.

During summer 2005, 48-hour DO fluctuations (Appendix C) indicated that DO concentrations dropped below 5 mg/L for an average of approximately 26.75 hours (0.5 to 41.25 hours). The most severe consecutive excursions lasted an average of 11.58 hours (ranging from 2.0 to 19.5 hours). During summer 2006, 48-hour DO fluctuations (Appendix C) indicated that DO concentrations dropped below 5 mg/L for an average of approximately 39.05 hours (22.75 hours to 48.75 hours). In 2006, the most severe consecutive excursions lasted an average of 26.05 hours (ranging from 11.0 to 37.25 hours).

A closer review of the 48-hour DO fluctuations revealed that DO concentrations were maintained above 2 mg/L during summer 2005 and 2006 with a few exceptions. During summer 2005, DO concentrations at C-2, C-4, C-7, and C-8 dropped below 2 mg/L for an hour to several hours.

During summer 2006, DO concentrations at C-2, C-4, C-6, C-7, C-8 and C-10 dropped below 2 mg/L for an hour to several hours. Typically, concentrations did not drop below 1 mg/L.

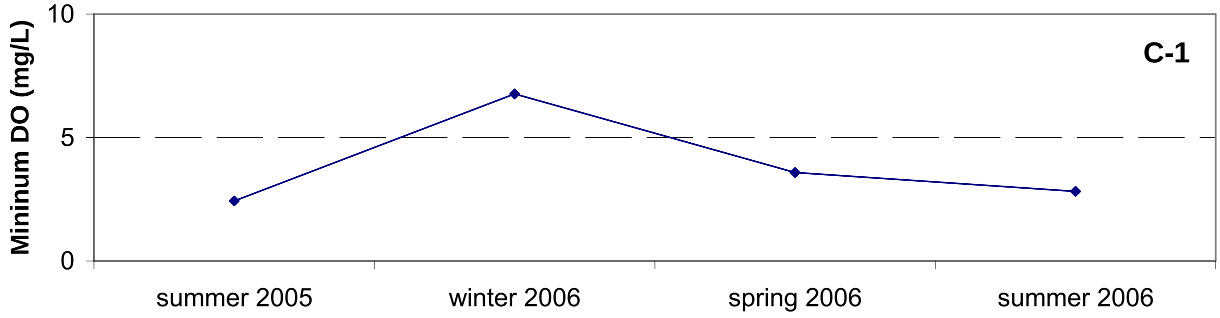

Figure 5-11. Minimum DO at Location C-1

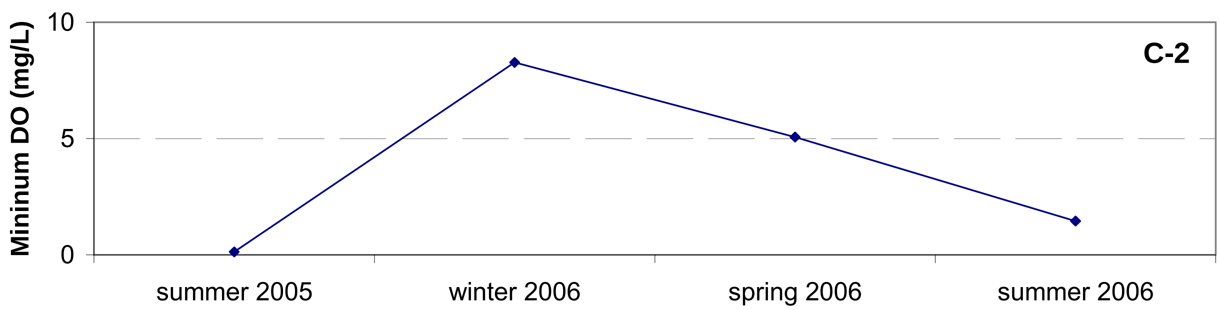

Figure 5-12. Minimum DO at Location C-2

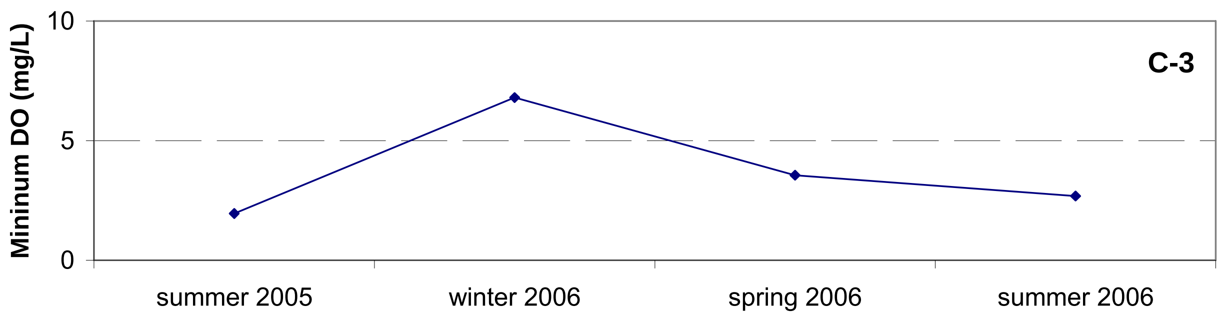

Figure 5-13. Minimum DO at Location C-3

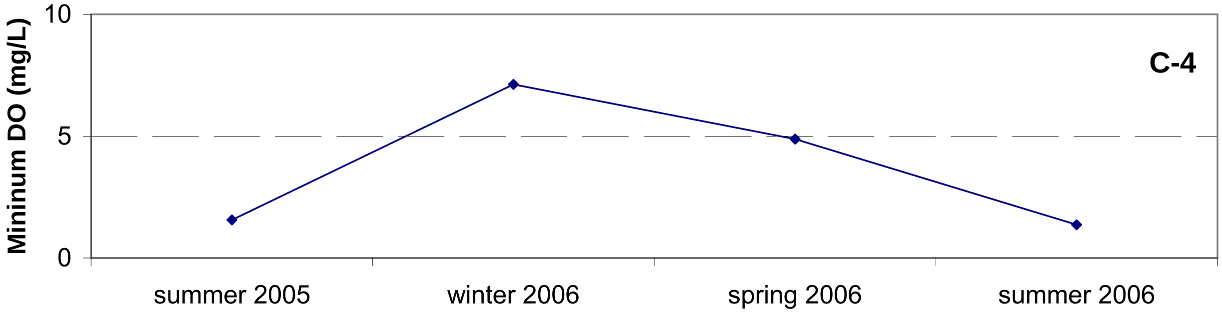

Figure 5-14. Minimum DO at Location C-4

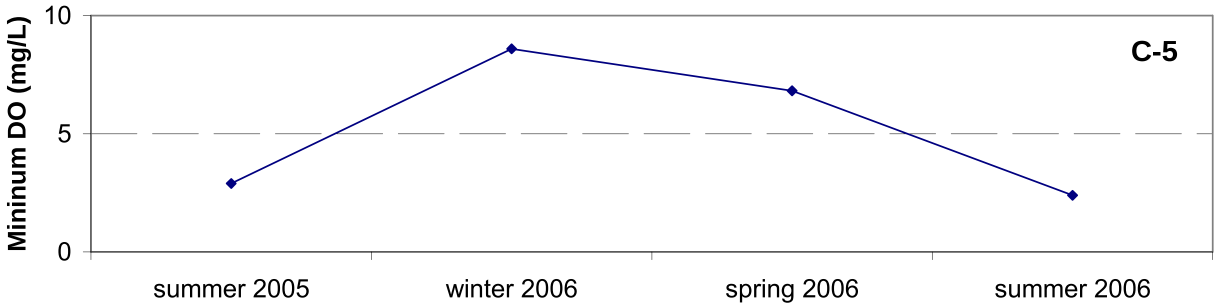

Figure 5-15. Minimum DO at Location C-5

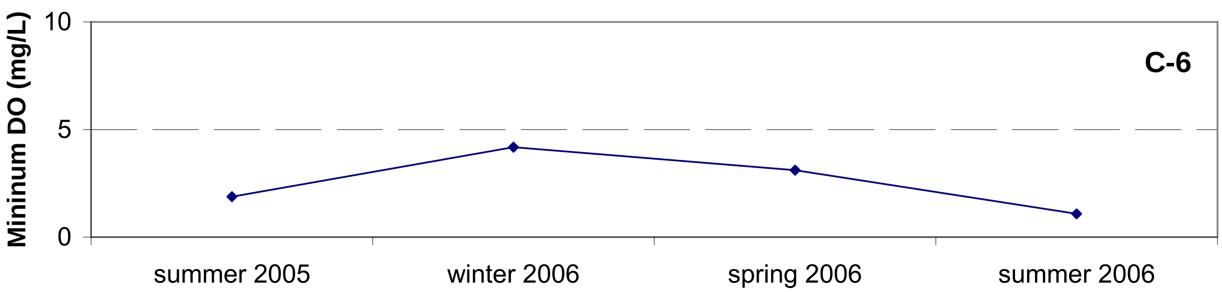

Figure 5-16. Minimum DO at Location C-6

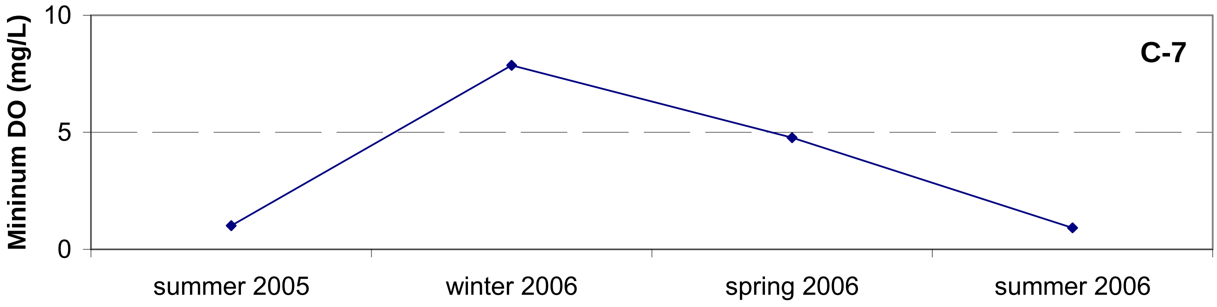

Figure 5-17. Minimum DO at Location C-7

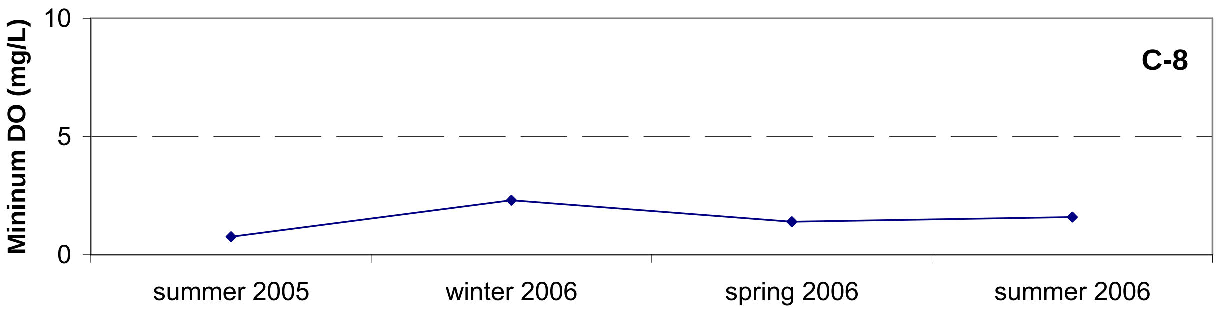

Figure 5-18. Minimum DO at Location C-8

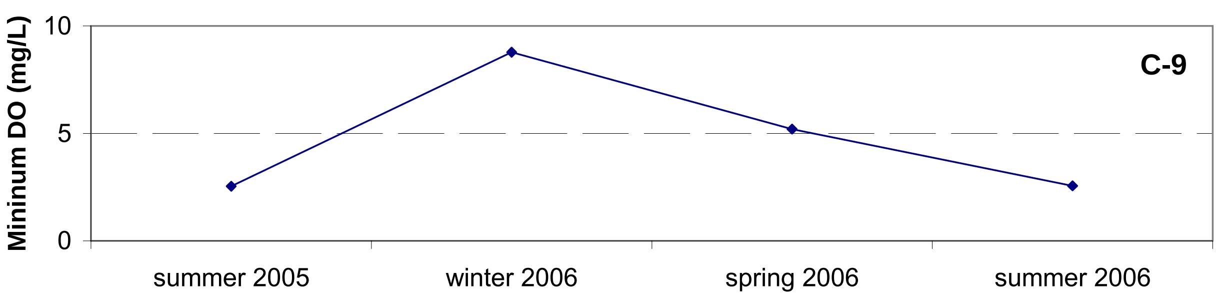

Figure 5-19. Minimum DO at Location C-9

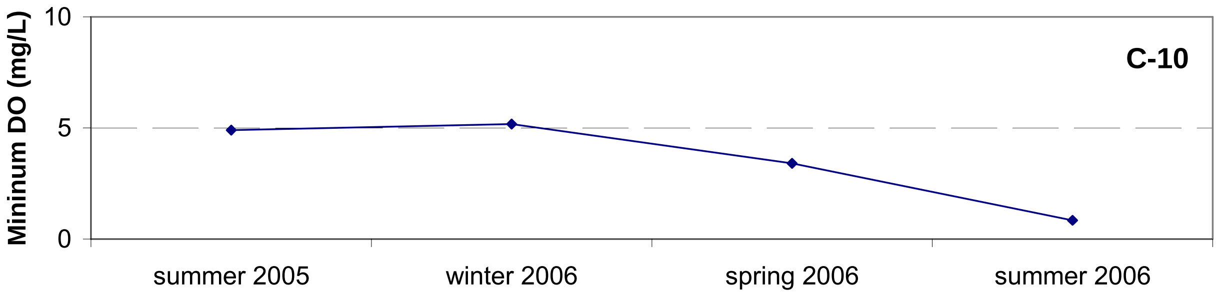

Figure 5-20. Minimum DO at Location C-10

The 48 hr records of continuous DO measurements at the 10 sites in summer 2005 and summer 2006 were constructed for each site using the cumulative distribution function (CDF) and are depicted on graphs presented in Appendix L. The CDF shows the probability that the value of a random variable is less than a specific value. An estimate of the percentage of time that DO values were below 5 mg/L is summarized in Table 5-1.

Table 5-1. Cumulative Distribution Function Summary for DO Continuous Monitoring at Locations C-1 to C-10

Site	Percent time below 5 mg/L DO standard	
	Summer 2005	Summer 2006
C-1	35	35
C-2	38	90
C-3	67	67
C-4	74	88
C-5	75	91
C-6	59	68
C-7	70	70
C-8	65	55
C-9	38	50
C-10	2	82

In summary, site C-5 appears to have the most depressed DO condition, while Site C-1 has the best DO condition based on CDFs during the critical season (Table 5-1).

Additionally, the average and minimum DO measurements of the 48 hour continuous monitoring data were characterized using cumulative distribution functions to define the percent of time across all 10 sites (aggregated) which fall below 5 mg/L (Table 5-2).

Table 5-2. Cumulative Distribution Function Summary for DO Continuous Monitoring at Locations C-1 to C-10 (Average and Minimum DO)

	Percent Time below 5 mg/L DO Standard[1]	
	Summer 2005	Summer 2006
Average DO	55	75
Minimum DO	100	100

[1]The estimated percentage of time across all 10 sites that the average DO or minimum DO was below the 5 mg/L standard.

5.1.2 Other Water Quality Characteristics

Minor excursions of the pH water quality criteria occurred at some sites. Generally, values that exceed the acceptable pH range were only temporarily observed during the 48-hour monitoring period. As expected, exceedances of the maximum temperature water quality standard primarily occurred during the critical period (summer 2005 and summer 2006). Salinity was typically low (<0.25 ppt) and did not exhibit marked seasonal variability. One exception is that salinity was increased at sites C-7, C-8, C-9, and C-10 during winter 2006. This is probably a reflection of residual impacts caused by the August and September 2005 hurricanes. The greatest increase in salinity was observed at C-10 with an average of 0.10 ppt in summer 2005 which increased to an average of 0.88 ppt during winter 2006. Using 50 NTU as a guideline (LDEQ 2006), some sporadic exceedances were observed but, overall, turbidity was low at all sites. Although some variability was observed in nitrogen, total phosphorus and other water quality indicator parameters, there was not an indication of significant nutrient loading at the sites.

5.1.3 Habitat Characteristics

Forested wetland was the primary surrounding habitat type. Considerable variability in habitat characteristics was observed. Based on presence of submerged, emergent, and floating vegetation, two sites, C-1 (intermediate stream) and C-9 (open water), had the least available habitat. Both sites also had a high clay content substrate and low TOC. Site C-3 (large stream/open water) did not have emergent vegetation within the sample reach and had high clay content.

5.1.4 Benthic Macroinvertebrate Communities

A summary of the benthic macroinvertebrates collected in 2005 is presented in Table 5-3 and Table 5-4. Table 5-5 provides a summary of "best candidate metrics" for dip net samples collected during 2005.

The comparative evaluation of the benthic macroinvertebrate communities was based upon two key metrics: species richness and Shannon-Wiener Diversity. Although other metrics were calculated, these two metrics were selected as they are the most robust, widely accepted, and comparable across the range of sites sampled in this investigation. For dip net samples, species richness ranged from 13 to 38 and total number of individuals ranged from 63 to 19310 (Table 5-3). Shannon-Weiner diversity was highest at C-6 (3.71) and lowest at C-4 (1.49). For ponar samples, species richness ranged from 3 to 38 and total number of individuals ranged from 10 to 8821 (Table 5-4). Shannon-Weiner diversity was highest at C-4 (3.65) and lowest at C-10 (0.25). In general, dominant taxa for dip net samples were tolerant taxa such as *Hyallela azteca*, *Palaemonetes kadiakensis*, *Caenis*, and *Glyptotendipes*. Dominant taxa for ponar samples were also represented by tolerant taxa such as Tubificidae, *Caenis*, Chironomidae, *Glyptotendipes*, and *Hyallela azteca.*

Table 5-3. Summary of Benthic Macroinvertebrate Analysis of Dip Net Samples Collected from Sites C-1 through C-10, Terrebonne Basin, Louisiana, Summer 2005

	C-1	C-2*	C-3	C-4	C-5	C-6	C-7	C-8	C-9	C-10
Total individuals	63	557	217	279	280	258	10493	3417	19310	2576
Number of Species	13	38	16	20	27	28	25	32	24	23
Shannon-Weiner Diversity-bits	2.67	3.59	2.78	1.49	3.26	3.71	2.86	3.36	1.62	3.36
Density #/Meter^2	20.32	179.68	70.00	90.00	90.32	83.23	3384.68	1102.26	7401.10	830.97

*Dip net and ponar samples composited for this site

Table 5-4. Summary of Benthic Macroinvertebrate Analysis of Ponar Samples Collected from Sites C-1 through C-10, Terrebonne Basin, Louisiana, Summer 2005

Metric	C-1	C-2*	C-3	C-4	C-5	C-6	C-7	C-8	C-9	C-10
Total individuals	10	557	43	154	34	30	329	186	8821	2163
Number of Species	4	38	11	24	9	11	13	19	7	3
Shannon-Weiner Diversity-bits	1.69	3.59	2.49	3.65	1.71	2.66	1.68	3.24	0.39	0.25
Density #/Meter^2	0.70	179.68	2.99	10.72	2.37	431.03	22.90	12.95	613.32	150.54

*Dip net and ponar samples composited for this site

Table 5-5. Best Candidate Metrics of Benthic Macroinvertebrates Analysis of Dip Net Samples Collected from Sites C-1 through C-10, Terrebonne Basin, Louisiana, Summer 2005

Station	Richness Measures					Composition Measures		Tolerance/Intolerance Measures			Feeding Measures		Habit Measures	
	total Taxa	# of EPT taxa	Ephemeroptera taxa	Plecoptera taxa	Trichoptera	% EPT	% Ephemeroptera	% Tolerant Taxa	# of Intolerant Taxa	% Dominant Taxa	% Filter Feeders	% Grazer / Scrapers	# of Clinger Taxa	% Clinger Taxa
C-1	13	2	2	0	0	3.17	3.17	15.87	0	31.75	11.11	0.00	0	0.00
C-2	38	4	4	0	0	2.03	2.03	37.02	2	26.34	2.39	5.34	0	0.00
C-3	16	2	1	0	1	41.94	41.47	88.02	0	41.47	0.00	1.84	0	0.00
C-4	20	4	2	0	2	82.8	81.36	86.02	1	79.57	0.36	5.02	0	0.00
C-5	27	2	2	0	0	3.57	3.57	31.43	0	34.64	0.71	7.86	1	1.43
C-6	28	2	2	0	0	6.98	6.98	31.78	0	20.16	0.00	4.65	0	0.00
C-7	25	3	2	0	1	5.66	4.72	74.4	0	41.28	41.52	2.59	0	0.00
C-8	32	3	2	0	1	13.29	11.12	73.43	0	37.9	13.05	6.79	0	0.00
C-9	24	2	2	0	0	2.29	2.29	93.32	0	90.27	0.19	0.19	1	0.19
C-10	23	1	1	0	0	4.31	4.31	68.75	0	31.72	0.00	23.06	1	0.47

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A summary of the benthic macroinvertebrates collected in 2006 is presented in Table 5-6 (for dip net samples) and Table 5-7 (for ponar samples). For dip net samples, species richness ranged from 10 to 43 and total number of individuals ranged from 57 to 14,716. Number of benthic invertebrate individuals varied significantly among sites (Kruskal-Wallis $P<0.0001$). Shannon-Weiner diversity was highest at C-5 (4.42) and lowest at C-8 (1.22). The Hilsenhoff Biotic Index (HBI) is included for discussion purposes to include another common benthic invertebrate community metric. The HBI was originally developed to assess low DO caused by organic loading which potentially makes it an important metric for this study. HBI values range from 0 to 10 (lower values indicate excellent water quality and higher values indicate poor water quality) and calculation of the metric is dependent on availability of species specific tolerance values. Interestingly, HBI values were high at ratings of poor and very poor.

For ponar samples collected in 2006, species richness ranged from 9 to 32 and total number of individuals ranged from 32 to 392 (Table 5-7). Number of benthic invertebrate individuals varied significantly among sites (Kruskal-Wallis $P=0.0007$). Shannon-Weiner diversity was highest at C-3 (3.66) and lowest at C-9 (1.05). HBI values were high at ratings of fairly poor, poor, and very poor.

For both dip net samples and ponar samples, bivariate plots of DO concentrations (average and minimum) and benthic species richness and diversity showed no clear biologically significant relationship (Figures 5-21 through 5-36). The lack of relationship is illustrated by benthic species richness being higher at locations with lower DO and locations with higher DO having lower species richness. Similarly, higher benthic diversity was observed at locations with lower DO. Similar results were obtained when plotting discrete measurements of DO collected during the benthic sampling event. Therefore, regression analysis was not evaluated as no biologically significant trend was apparent.

In general, dominant taxa for dip net samples (e.g., vegetation) were tolerant taxa such as *Parachironomous* sp (chironomid midge) and *Dero* sp. (oligochaete) (See Appendix I). Dominant taxa for ponar samples (e.g., sediment) were also represented by tolerant taxa such as *Campsurus decoloratus* (mayfly), Tubificidae without cap setae (worm), Ceratopogoninae (predacious midges), and *Caenis diminuta* (mayfly).

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Table 5-6. Summary of Benthic Macroinvertebrate Analysis of Dip Net Samples Collected from Sites C-1 through C-10, Terrebonne Basin, Louisiana, Summer 2006

Metric	C-1	C-2	C-3	C-4	C-5	C-6	C-7	C-8	C-9	C-10
Total individuals	57	329	319	335	397	337	309	220	247	337
Corrected Abundance	57	717.22	1605.9	381.9	7411.99	5392	5191.2	14716.8	2371.2	4718
Number of Species	18	38	32	30	37	43	32	10	31	39
Shannon-Weiner Diversity-bits	3.39	3.91	3.5	3.05	4.42	4.32	3.36	1.22	3.51	4.28
EPT richness	1	4	4	4	3	4	1	1	2	3
EPT index	0.02	0.10	0.15	0.26	0.08	0.09	0.01	0.02	0.05	0.07
EPT/EPT Chironomids	0.03	0.18	0.24	0.92	0.16	0.24	0.04	0.01	0.04	0.17
Scrapers/Scrapers + Filterers	0.67	1	1	0.75	0.5	0.83	0.75	0	1	0.8
Hilsenhoff Biotic Index	7.64	8.76	8.71	9.12	7.62	8.38	7.85	8.02	8.17	8.02

Table 5-7. Summary of Benthic Macroinvertebrate Analysis of Ponar Samples Collected from Sites C-1 through C-10, Terrebonne Basin, Louisiana, Summer 2006

Metric	C-1	C-2	C-3	C-4	C-5	C-6	C-7	C-8	C-9	C-10
Total individuals	91	79	70	238	326	98	371	239	54	32
Corrected Abundance	91	79	70	238	391.2	98	371	239	54	32
Number of Species	18	18	18	25	29	12	32	23	9	14
Shannon-Weiner Diversity-bits	2.77	2.86	3.66	3.37	2.82	2.77	3.31	3.38	1.05	3.44
EPT richness	2	2	2	4	3	1	2	1	0	1
EPT index	0.11	0.11	0.11	0.15	0.1	0.03	0.03	0.01	0	0.19
EPT/EPT Chironomids	0.07	0.86	0.90	0.91	0.94	1	0.07	0.04	0	0.43
Scrapers/Scrapers + Filterers	0.5	NA	0.75	0.67	0.67	0.67	0.5	0.5	1	0
Hilsenhoff Biotic Index	8.76	7.06	7.59	8.12	8.43	6.50	7.53	8.10	9.60	7.38

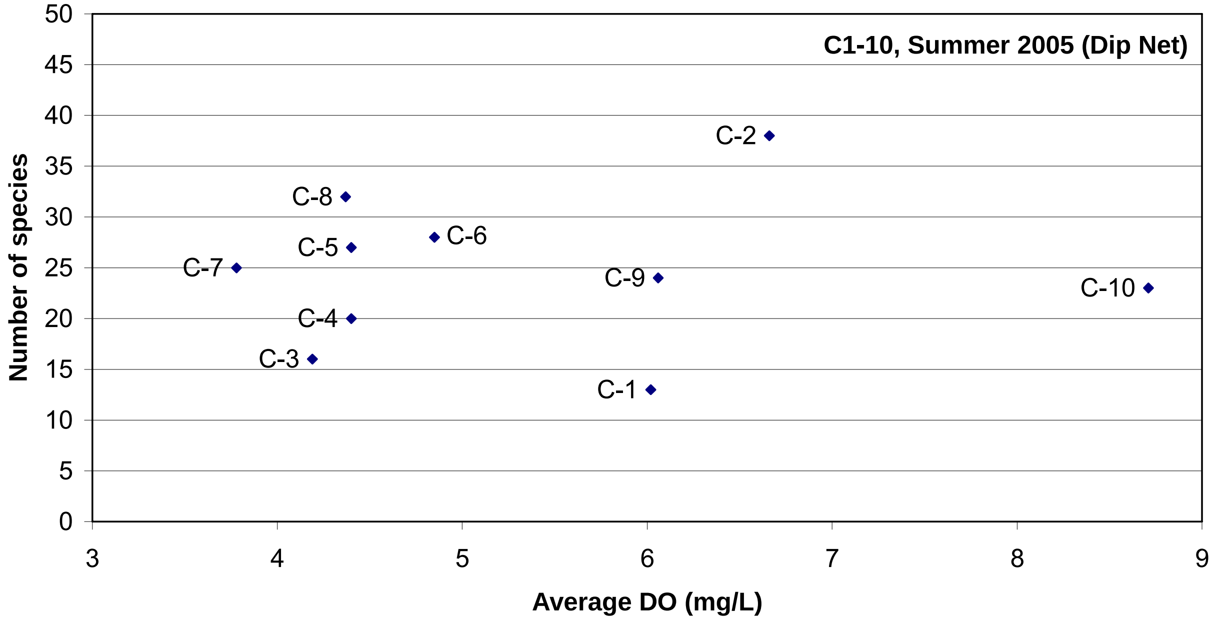

Figure 5-21. Bivariate Plot of Average DO and Benthic Macroinvertebrate Species Richness (Dip Net) at Locations C-1 through C-10, Terrebonne Basin, Louisiana, Summer 2005

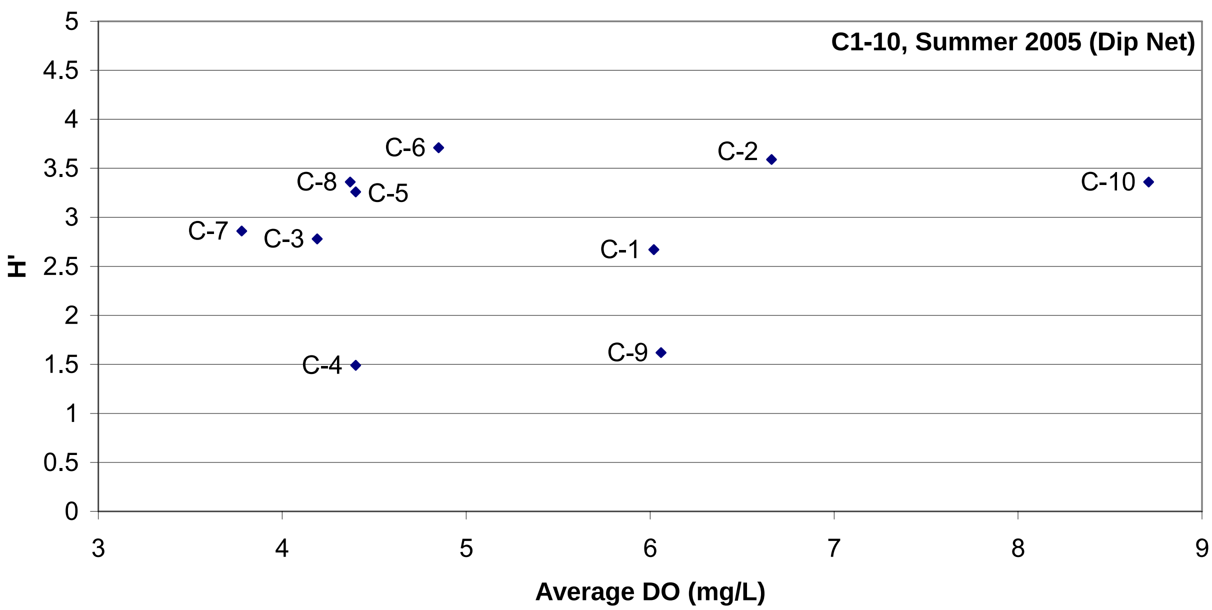

Figure 5-22. Bivariate Plot of Average DO and H' (Shannon-Weiner Diversity Bits) of Benthic Macroinvertebrate (Dip Net) at Locations C-1 through C-10, Terrebonne Basin, Louisiana, Summer 2005

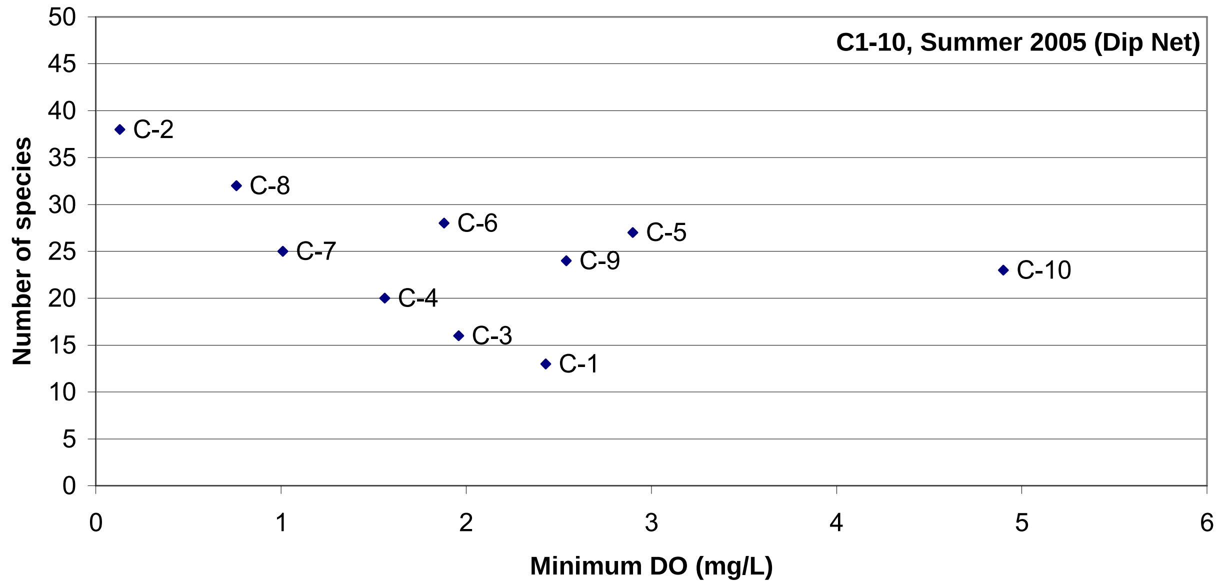

Figure 5-23. Bivariate plot of Minimum DO and Benthic Macroinvertebrate Species Richness (Dip Net) at Locations C-1 through C-10, Terrebonne Basin, Louisiana, Summer 2005

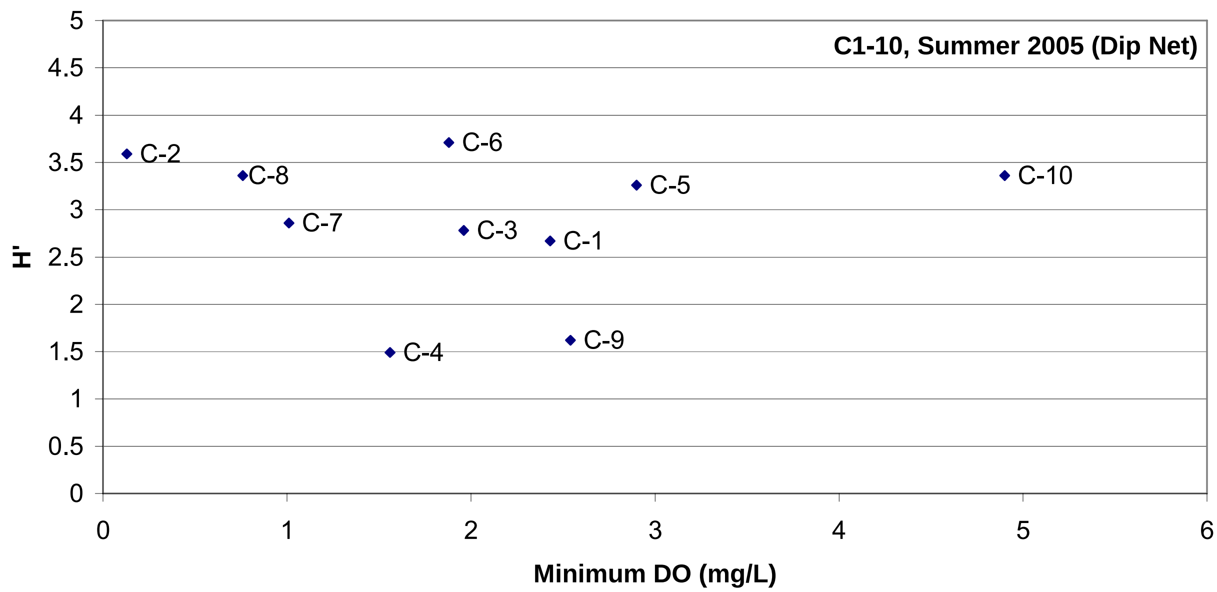

Figure 5-24. Bivariate Plot of Minimum DO and H' (Shannon-Weiner Diversity Bits) of Benthic Macroinvertebrate (Dip Net) at Locations C-1 through C-10, Terrebonne Basin, Louisiana, Summer 2005

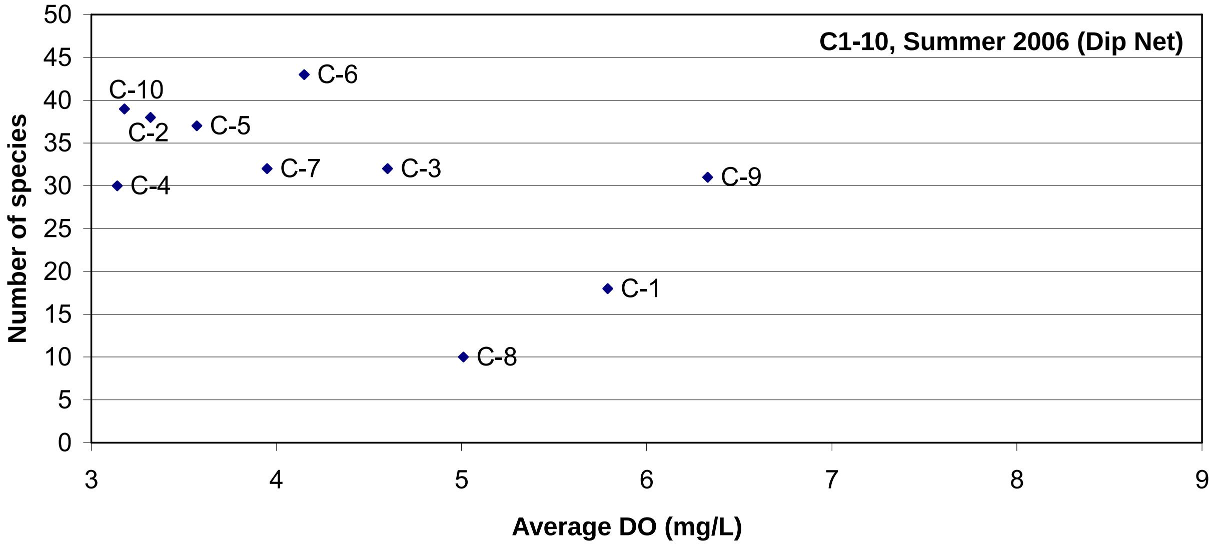

Figure 5-25. Bivariate Plot of Average DO and Benthic Macroinvertebrate Species Richness (Dip Net) at Locations C-1 through C-10, Terrebonne Basin, Louisiana, Summer 2006

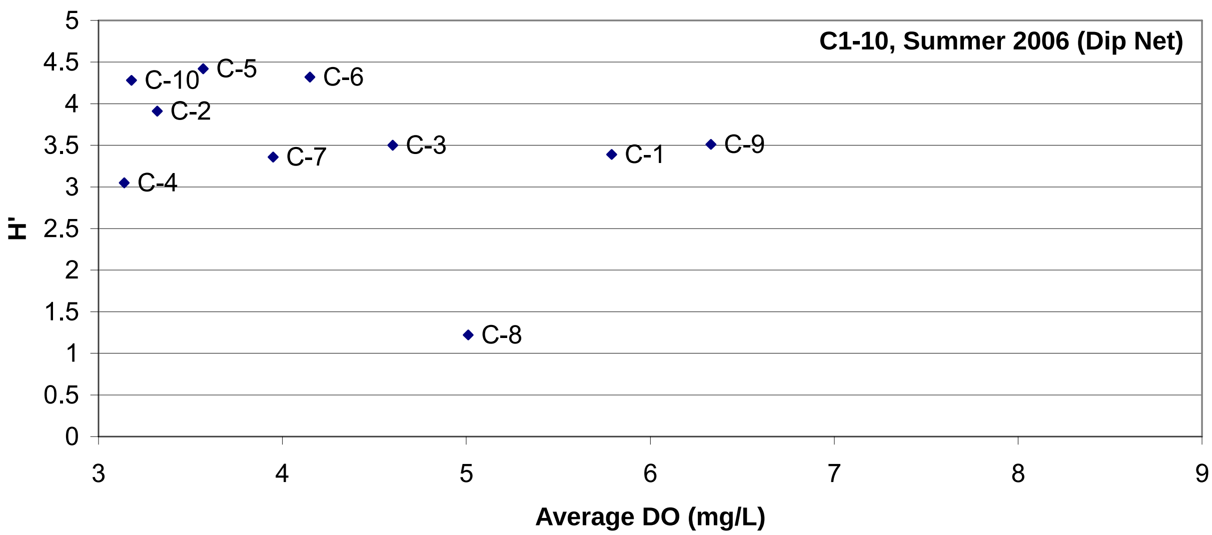

Figure 5-26. Bivariate Plot of Average DO and H' (Shannon-Weiner Diversity bits) of Benthic Macroinvertebrate (Dip Net) at Locations C-1 through C-10, Terrebonne Basin, Louisiana, Summer 2006

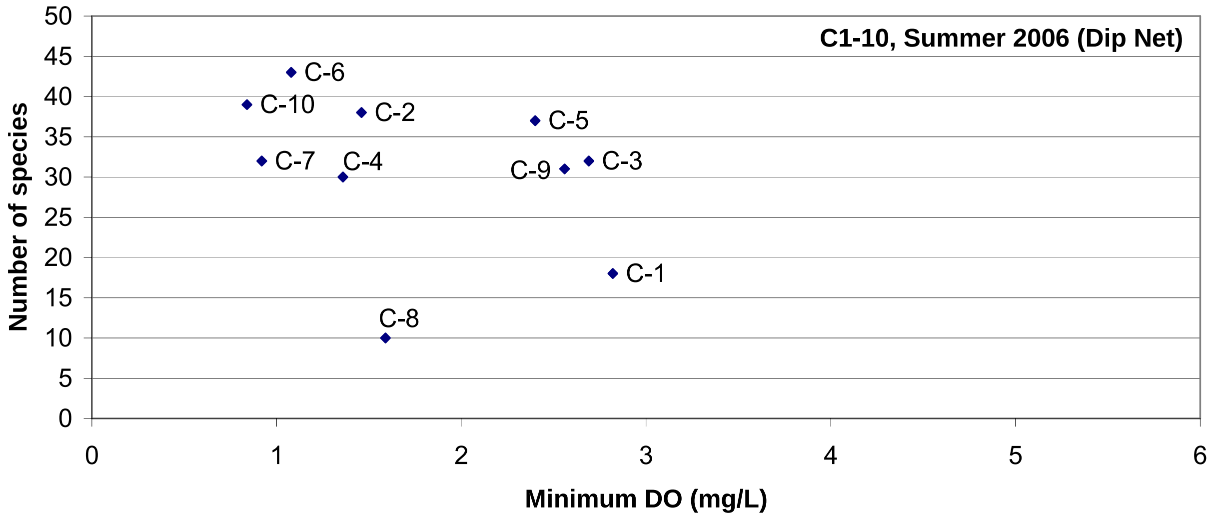

Figure 5-27. Bivariate Plot of Minimum DO and Benthic Macroinvertebrate Species Richness (Dip Net) at Locations C-1 through C-10, Terrebonne Basin, Louisiana, Summer 2006

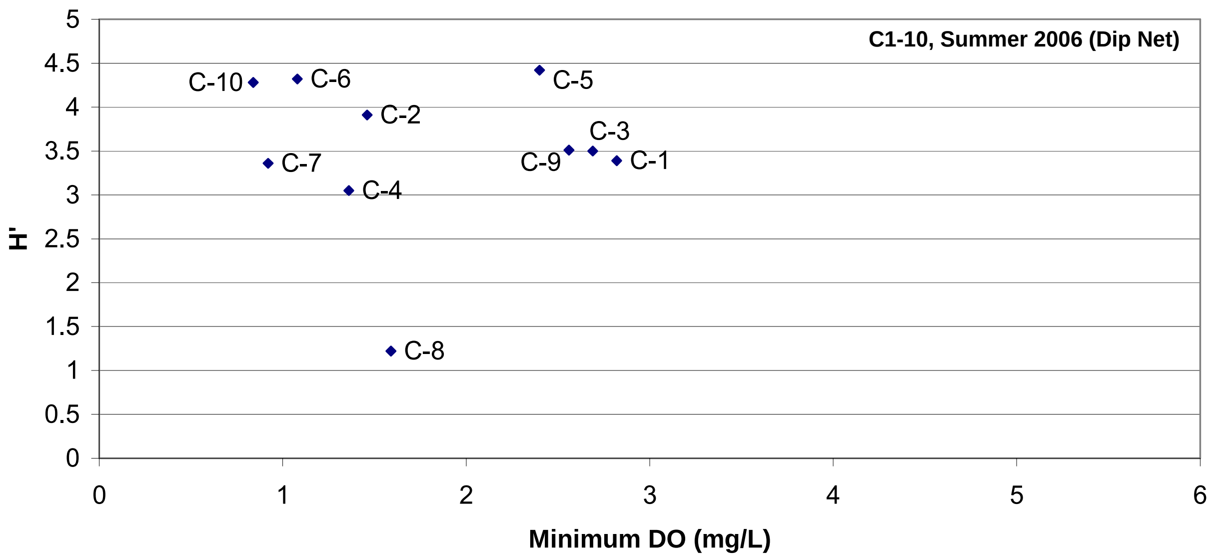

Figure 5-28. Bivariate Plot Of Minimum DO and H' (Shannon-Weiner Diversity Bits) of Benthic Macroinvertebrate (Dip Net) at Locations C-1 through C-10, Terrebonne Basin, Louisiana, Summer 2006

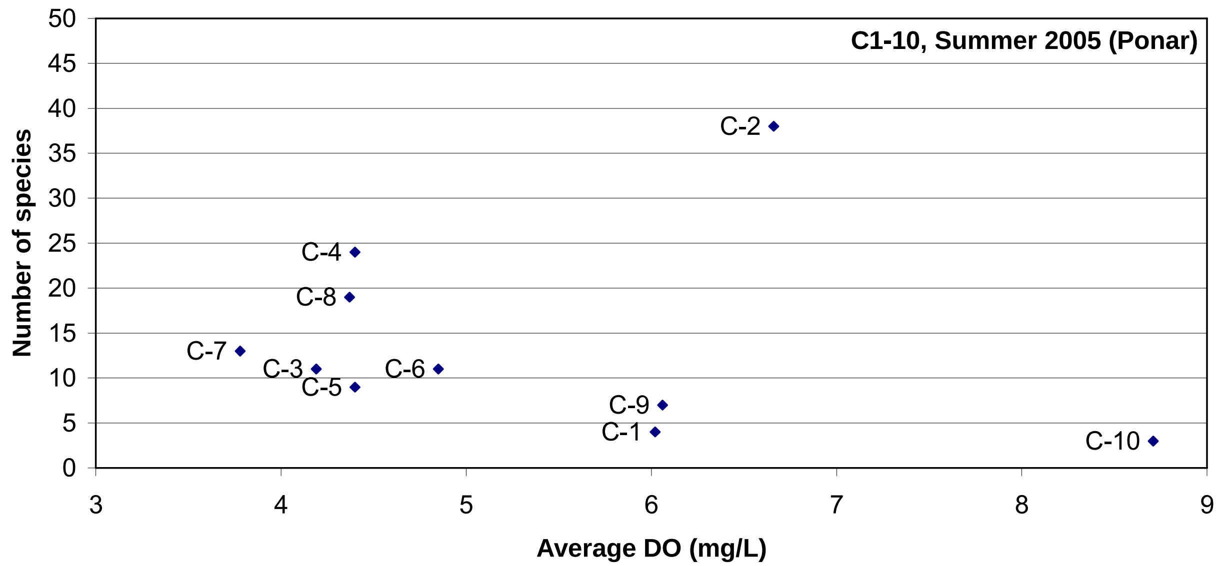

Figure 5-29. Bivariate Plot of Average DO and Benthic Macroinvertebrate Species Richness (Ponar) at Locations C-1 through C-10, Terrebonne Basin, Louisiana, Summer 2005

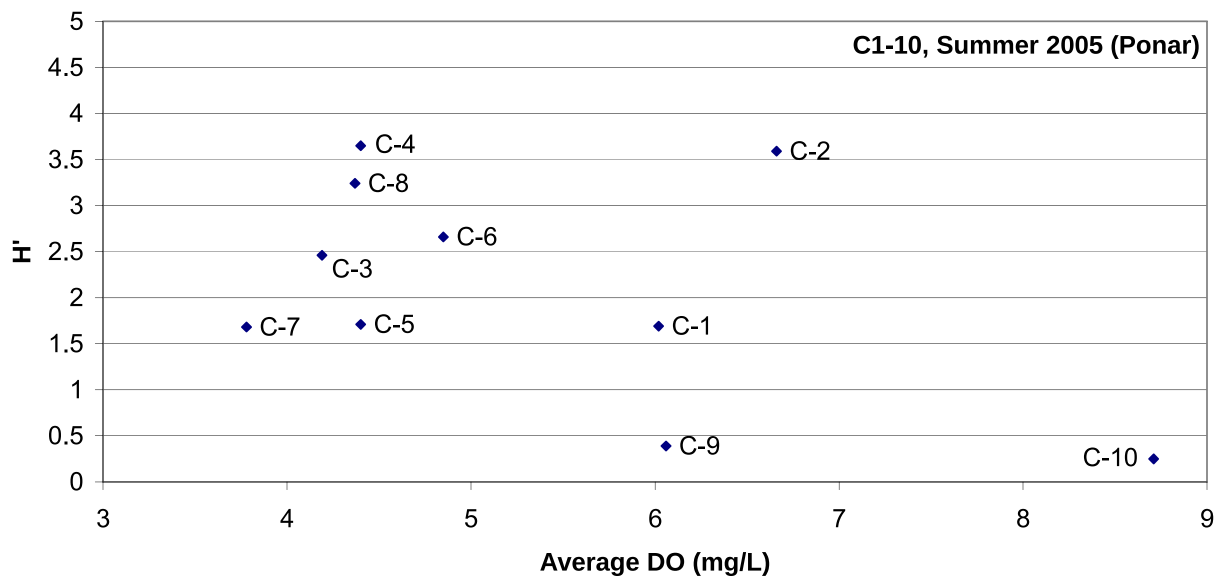

Figure 5-30. Bivariate Plot of Average DO and H' (Shannon-Weiner Diversity Bits) of Benthic Macroinvertebrate (Ponar) at Locations C-1 through C-10, Terrebonne Basin, Louisiana, Summer 2005

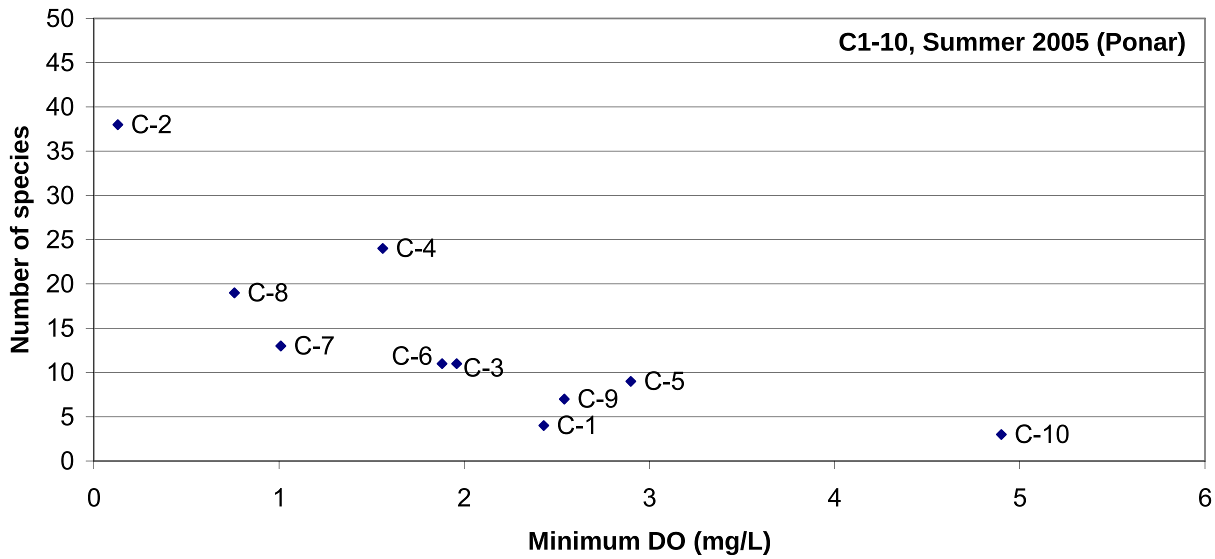

Figure 5-31. Bivariate Plot Of Minimum DO and Benthic Macroinvertebrate Species Richness (Ponar) at Locations C-1 through C-10, Terrebonne Basin, Louisiana, Summer 2005

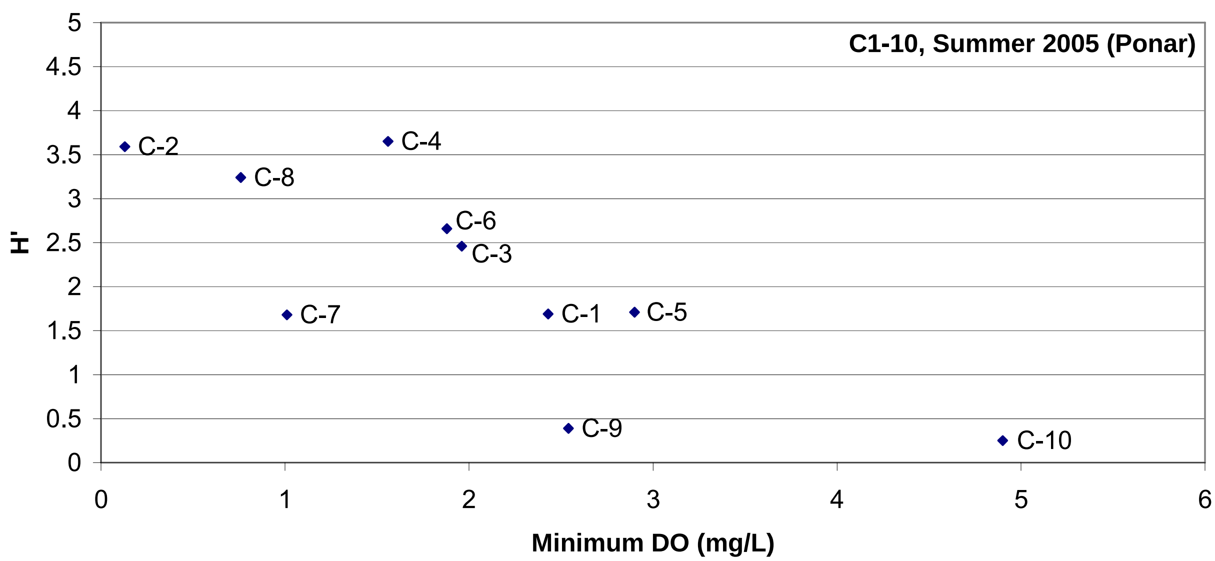

Figure 5-32. Bivariate Plot of Minimum DO and H' (Shannon-Weiner Diversity Bits) of Benthic Macroinvertebrate (Ponar) at Locations C-1 through C-10, Terrebonne Basin, Louisiana, Summer 2005

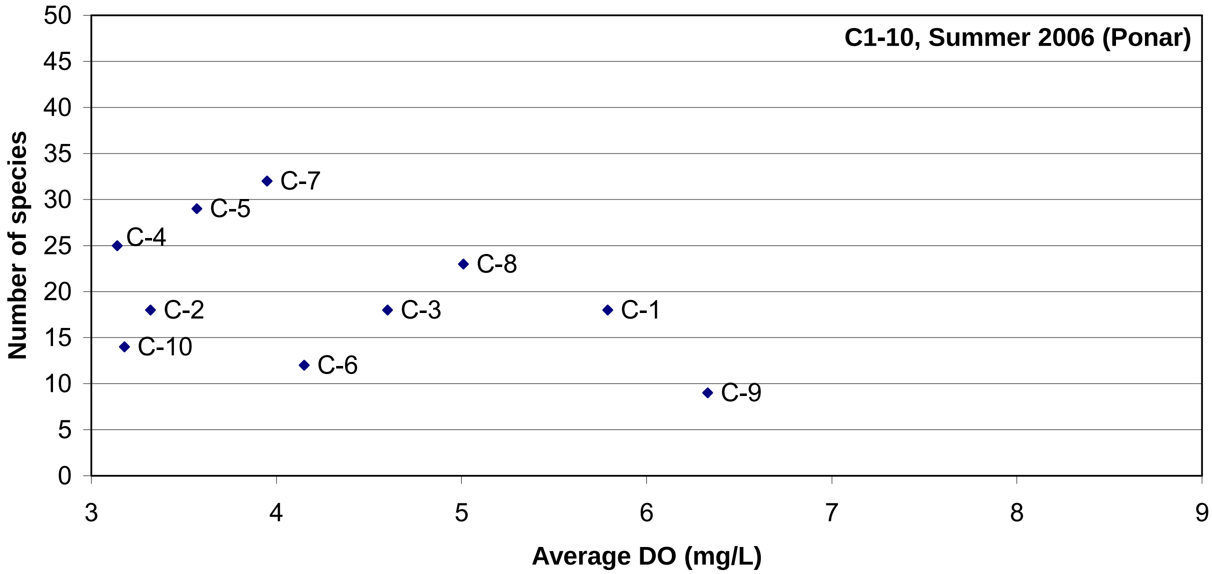

Figure 5-33. Bivariate Plot of Average DO and Benthic Macroinvertebrate species Richness (Ponar) at Locations C-1 through C-10, Terrebonne Basin, Louisiana, Summer 2006

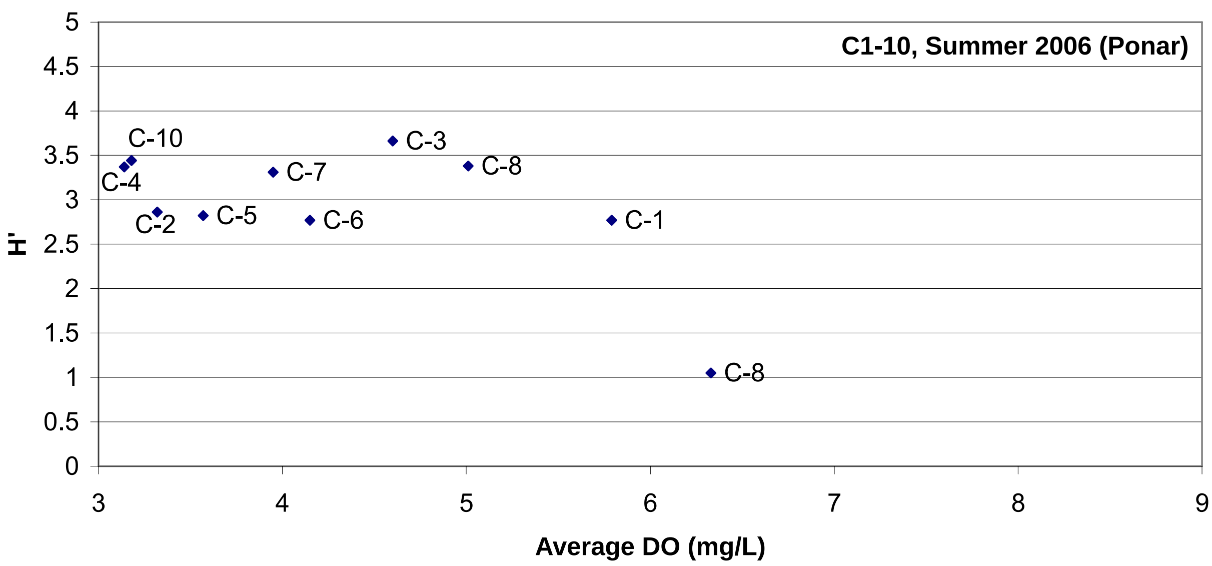

Figure 5-34. Bivariate Plot of Average DO and H' (Shannon-Weiner Diversity Bits) of Benthic Macroinvertebrate (Ponar) at Locations C-1 through C-10, Terrebonne Basin, Louisiana, Summer 2006

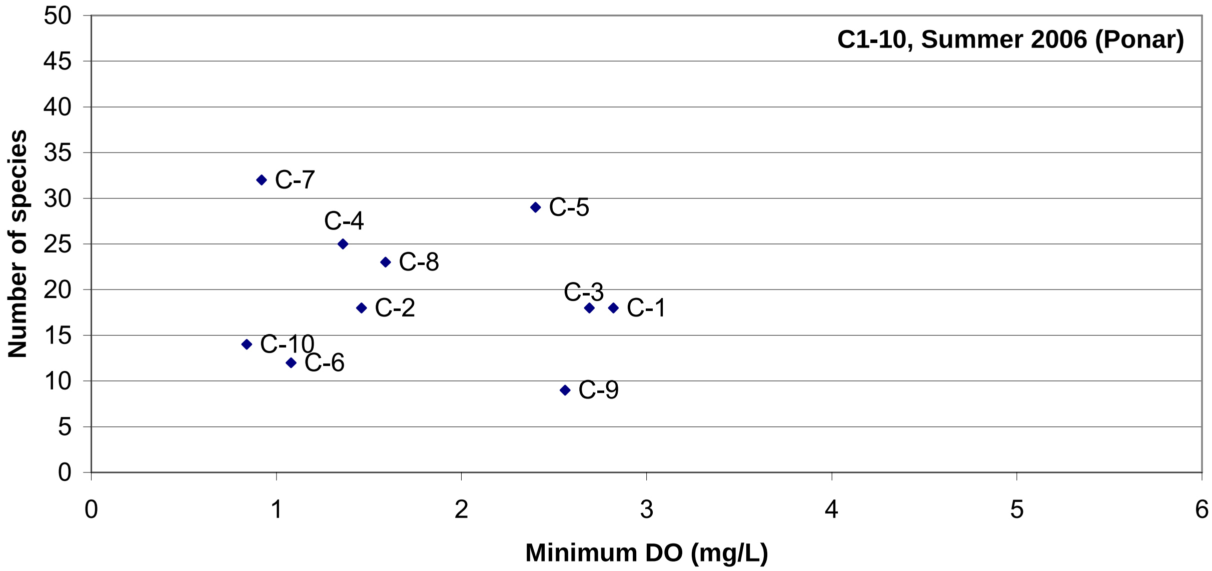

Figure 5-35. Bivariate Plot of Minimum DO and Benthic Macroinvertebrate Species Richness (Ponar) at Locations C-1 through C-10, Terrebonne Basin, Louisiana, Summer 2006

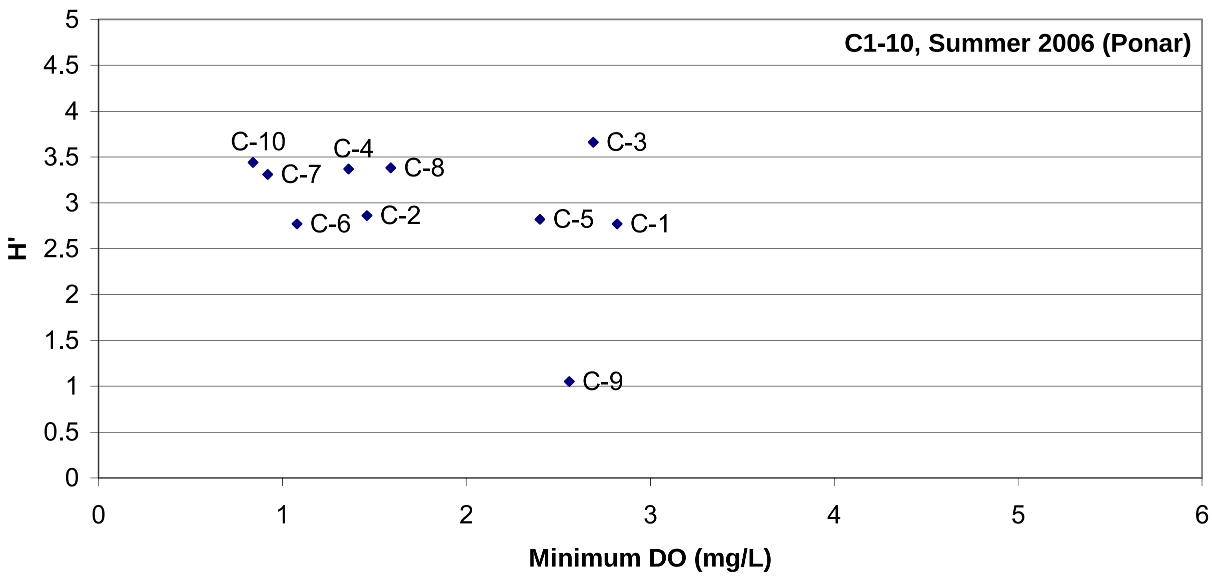

Figure 5-36. Bivariate Plot of Minimum DO and H' (Shannon-Weiner Diversity Bits) of Benthic Macroinvertebrate (Ponar) at Locations C-1 through C-10, Terrebonne Basin, Louisiana, Summer 2006

5.1.5 Fish Communities

Species richness ranged from 8 to 15 and total number of individuals ranged from 74 to 199 (Table 5-8). Number of individual fish did not vary significantly among sites (Kruskal-Wallis P=0.06). Shannon-Weiner diversity was highest at C-2 (3.24) and lowest at C-9 (1.78). Bivariate plots of DO concentrations (average and minimum) and fish species richness and diversity showed no clear biologically significant relationship (Figures 5-37 through 5-40). The lack of relationship is illustrated by fish species richness being higher at locations with lower DO, and locations with higher DO having lower species richness. Similarly, higher fish diversity was observed at locations with lower DO. Similar results were obtained when plotting discrete (Figures 5-41 and 5-42) measurements of DO collected during the fish sampling event. Therefore, regression analysis was not evaluated as no biologically significant trend was apparent.

In general, dominant taxa were centrarchids, shad, and spotted gar (Figures 5-43 through 5-44). A centrarchid species was dominant at every site except for C-7 and C-9. Shad and spotted gar were often the most dominant species.

Table 5-8. Summary of Total Individuals, Number of Species, and Shannon-Weiner Diversity of Fish Collected from Locations C-1 to C-10, Terrebonne Basin, Louisiana

Metric	C-1	C-2	C-3	C-4	C-5	C-6	C-7	C-8	C-9	C-10
Total Individuals	122	118	74	199	129	169	122	129	119	126
Number of Species	11	15	8	15	10	12	15	15	8	11
Shannon-Weiner Diversity -Bits	2.33	3.24	2.11	3.17	2.25	2.8	2.42	2.9	1.78	2.4

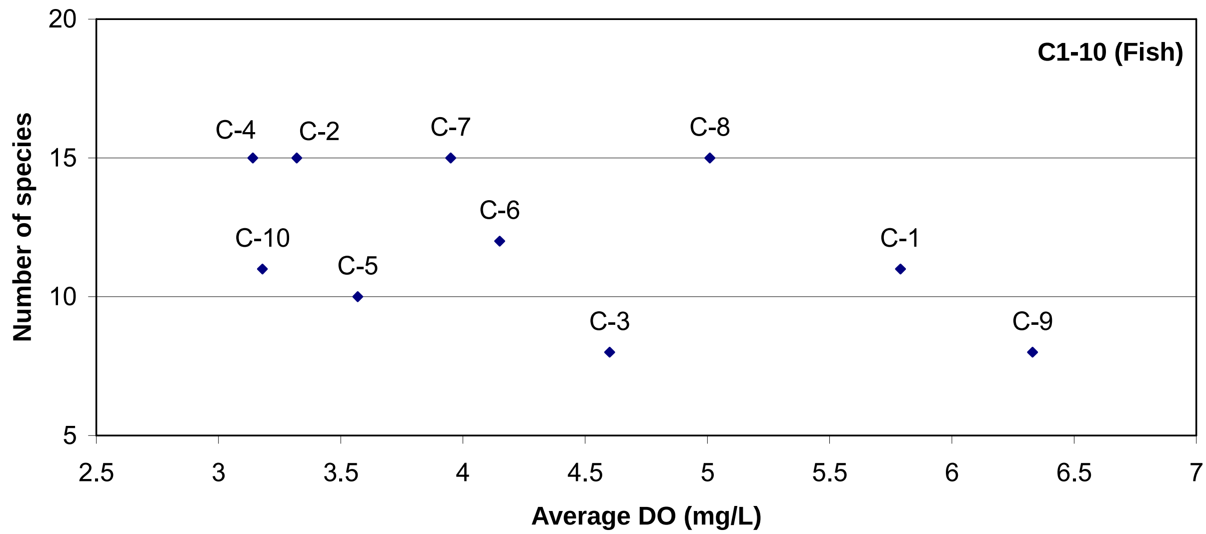

Figure 5-37. Bivariate Plot of Average DO and Fish Species Richness at Locations C-1 through C-10, Terrebonne Basin, Louisiana.

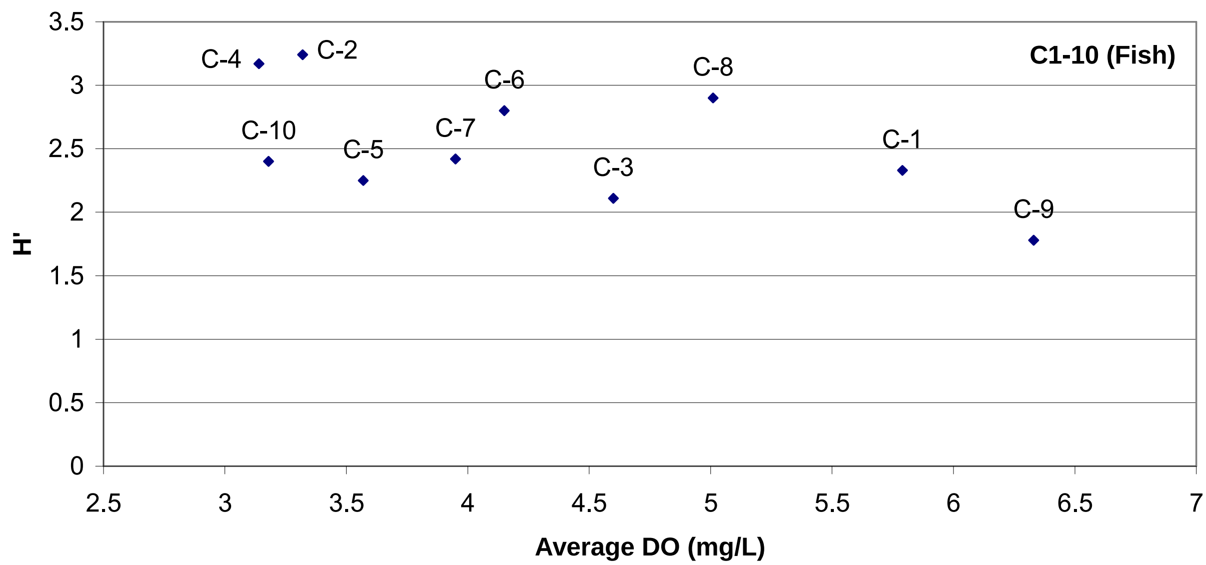

Figure 5-38. Bivariate Plot of Average DO and H' (Shannon-Weiner Diversity Bits) of Fish at Locations C-1 through C-10, Terrebonne Basin, Louisiana.

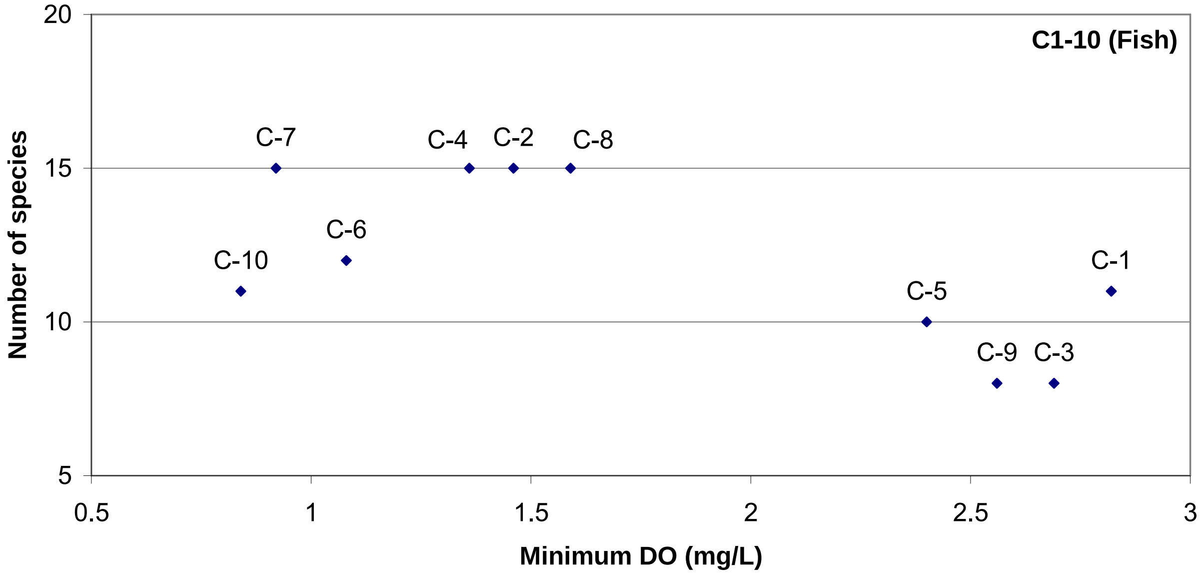

Figure 5-39. Bivariate Plot of Minimum DO and Fish Species Richness at Locations C-1 through C-10, Terrebonne Basin, Louisiana.

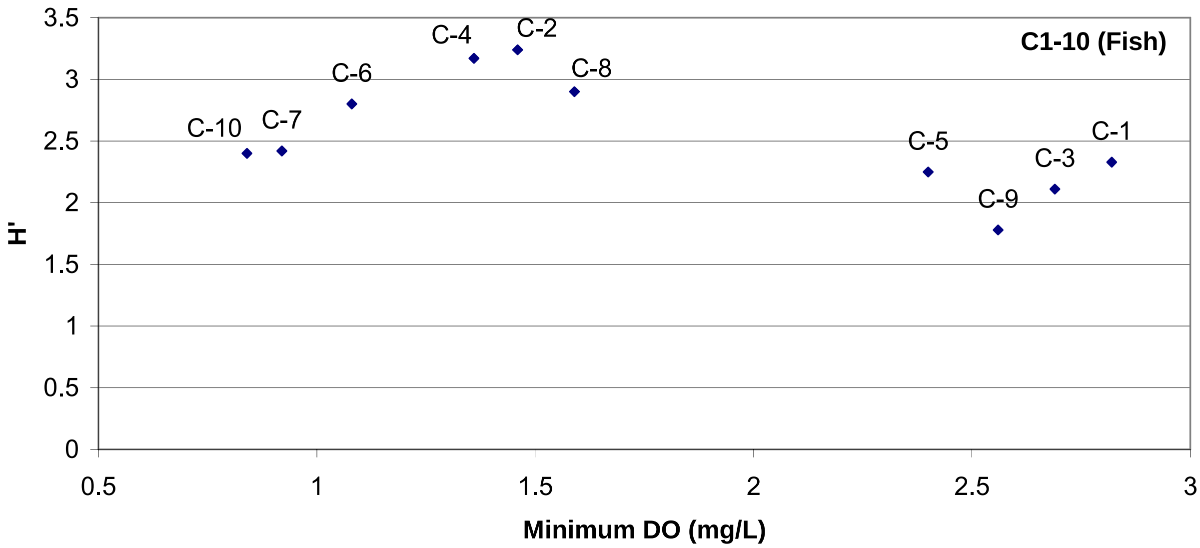

Figure 5-40. Bivariate Plot of Minimum DO and H' (Shannon-Weiner Diversity bits) of Fish at Locations C-1 through C-10, Terrebonne Basin, Louisiana.

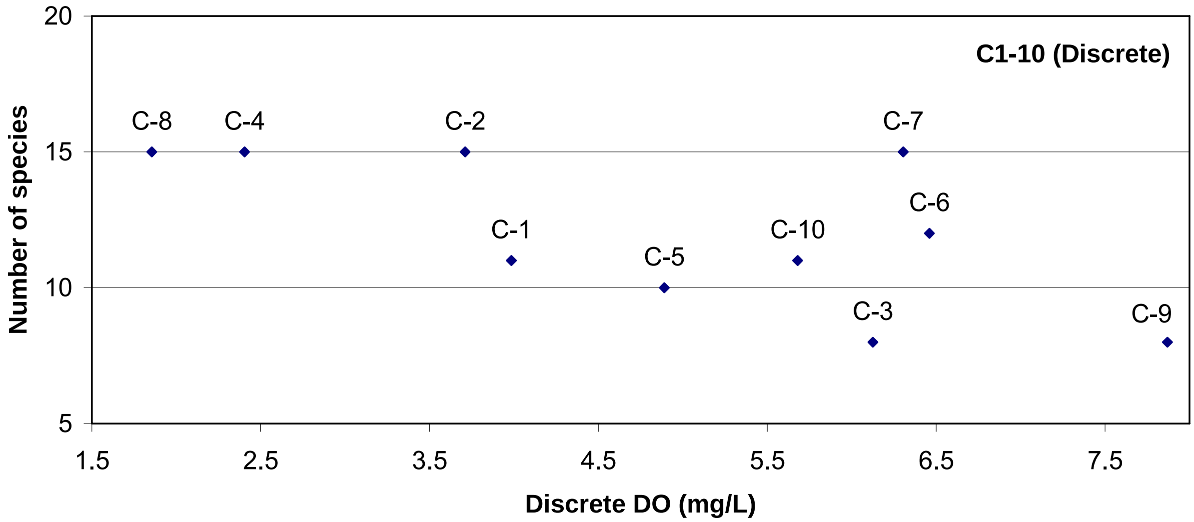

Figure 5-41. Bivariate Plot of Discrete DO and Fish Species Richness at Locations C-1 through C-10, Terrebonne Basin, Louisiana

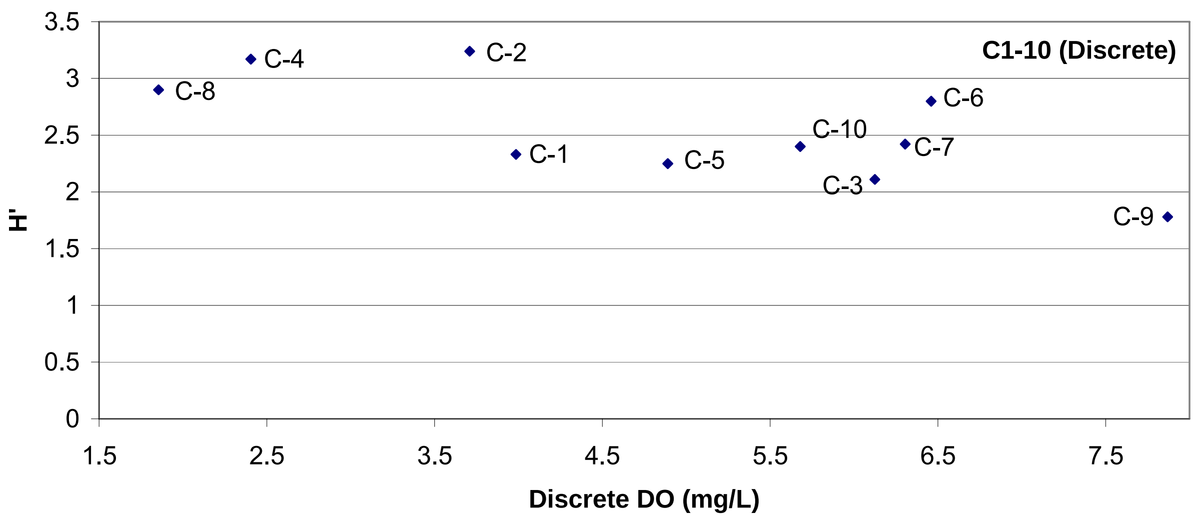

Figure 5-42. Bivariate Plot of Discrete DO and H' (Shannon-Weiner Diversity Bits) of Fish at Locations C-1 through C-10, Terrebonne Basin, Louisiana

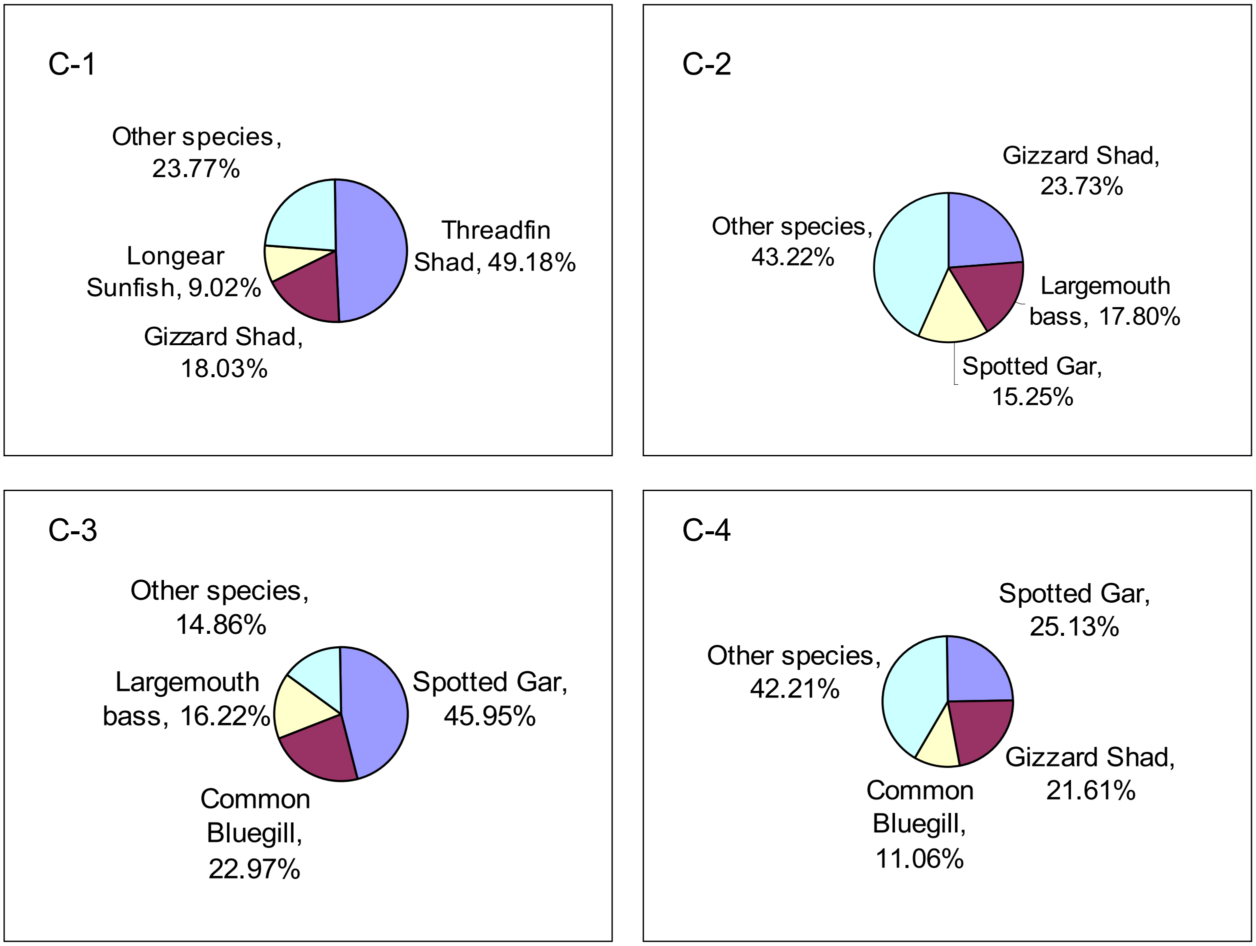

Figure 5-43. Dominant Fish Species at Sites C-1 through C-4

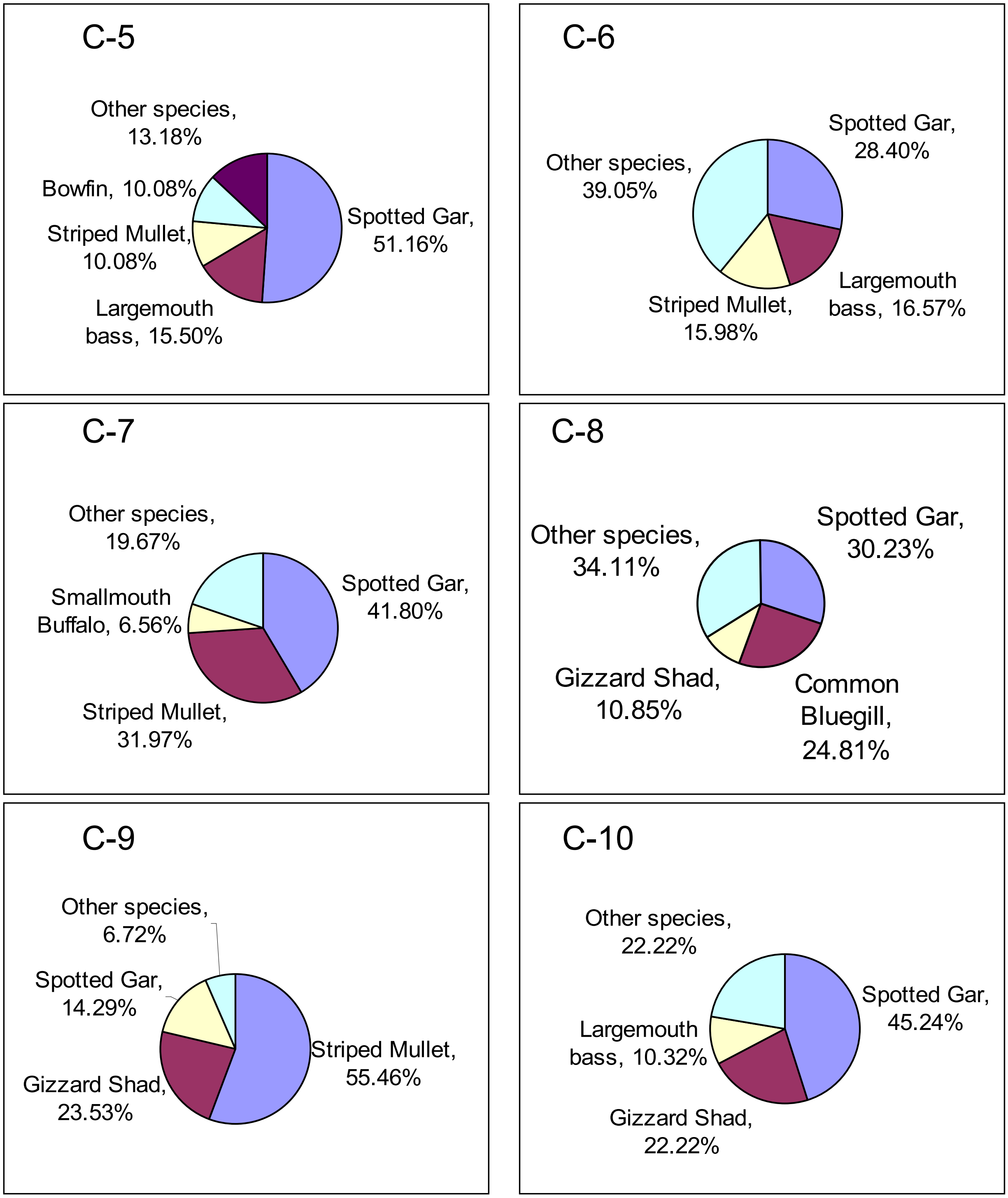

Figure 5-44. Dominant Fish Species at Sites C-5 through C-10

Of the fish species collected, black crappie, white crappie, largemouth bass, and catfish species would be most sensitive to low DO. Black crappie, white crappie, or largemouth bass were observed at every location except for C-9. Catfish were observed at all locations except C-1, C-3, C-5, and C-9. Based on fish community metrics, dominant taxa, and lack of sensitive indicator species, C-9 appears to have an impacted fish community.

5.2 Saltwater Sites C-11 through C-15

5.2.1 Dissolved Oxygen

Figures 5-45 through 5-49 present the average DO; error bars indicate the standard deviation. The 4 mg/L DO standard is also indicated for comparison.

Based on attainment of the 4 mg/L DO standard, all average DO values were above the standard (excluding abnormal data at C-12 during summer 2005). Excursions of minimum DO occurred primarily in summer 2005 and 2006 (Figures 5-50 through 5-54).

During summer 2005, 48-hour DO fluctuations (Appendix C) indicated that DO concentrations dropped below 4 mg/L for an average of approximately 10.9 hours (0 to 48.5 hours). The most severe consecutive excursions lasted an average of 0.56 hours (ranging up to 1.25 hours), excluding the abnormal data at C-12. During summer 2006, 48-hour DO fluctuations (Appendix C) indicated that DO concentrations dropped below 4 mg/L for an average of approximately 9.3 hours (0.5 to 23.75 hours). The most severe consecutive excursions lasted an average of 5.06 hours (ranging from 1 to 12.5 hours).

A closer review of the 48-hour DO fluctuations revealed that DO concentrations were maintained above 2 mg/L during summer 2005 and 2006 with only two exceptions. During summer 2005, DO concentrations at C-12 were anomalous and indicative of a sonde malfunction. During summer 2006, DO concentrations at C-13 dropped below 2 mg/L for approximately 1 hour. Typically, concentrations did not drop below 1 mg/L.

The 48 hr records of continuous DO measurements at the five sites in summer 2005 and summer 2006 were constructed for each site using the cumulative distribution function (CDF) and are depicted on graphs presented in Appendix L. An estimate of the percentage of time that DO values were below 4 mg/L is summarized in Table 5-9.

Additionally, the average and minimum DO measurements of the 48 hr continuous monitoring data combined across all five saltwater sites were characterized using CDF (Table 5-10).

Table 5-9. Cumulative Distribution Function Summary for DO Continuous Monitoring at Locations C-11 to C-15

Site	Percent time below 4 mg/L DO standard	
	Summer 2005	Summer 2006
C-11	0	10
C-12	NA	18
C-13	5	43
C-14	0	5
C-15	7	20

Table 5-10. Cumulative Distribution Function Summary for DO Continuous Monitoring at Locations C-11 to C-15 (Average and Minimum DO)

	Percent time below 4 mg/L DO standard[1]	
	Summer 2005	Summer 2006
Average DO	0	3
Minimum DO	58	100

[1] The estimated percentage of time, across all five sites, that the average DO or minimum DO was below the 4 mg/L standard.

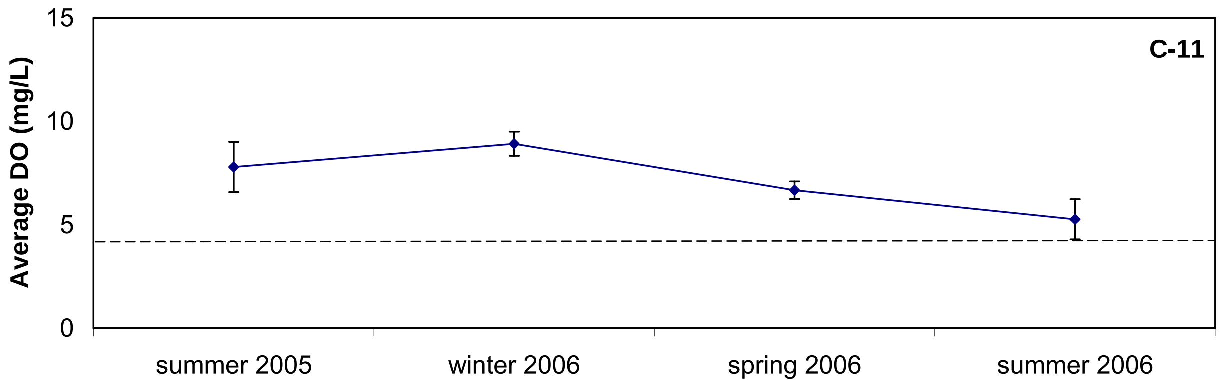

Figure 5-45. Average DO at Location C-11

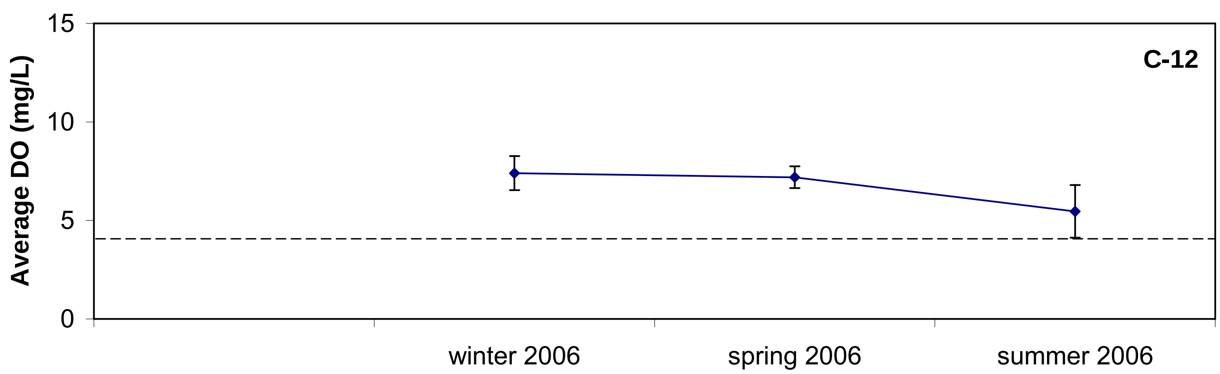

Figure 5-46. Average DO at Location C-12

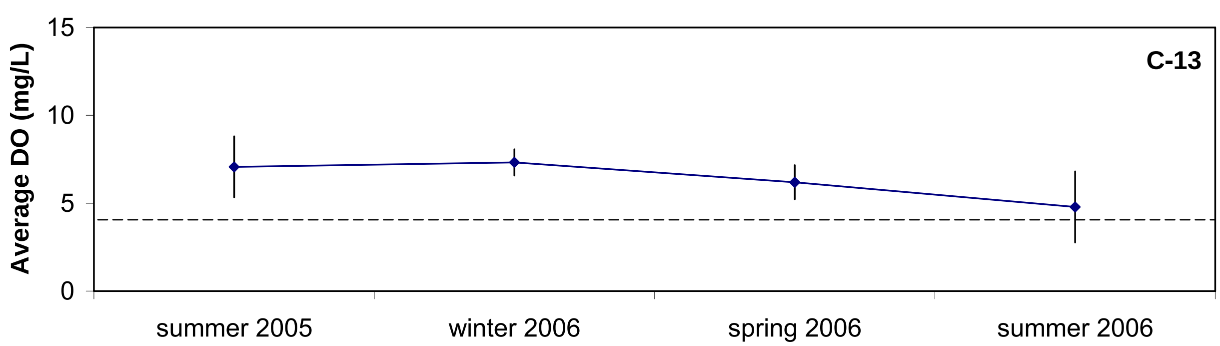

Figure 5-47. Average DO at Location C-13

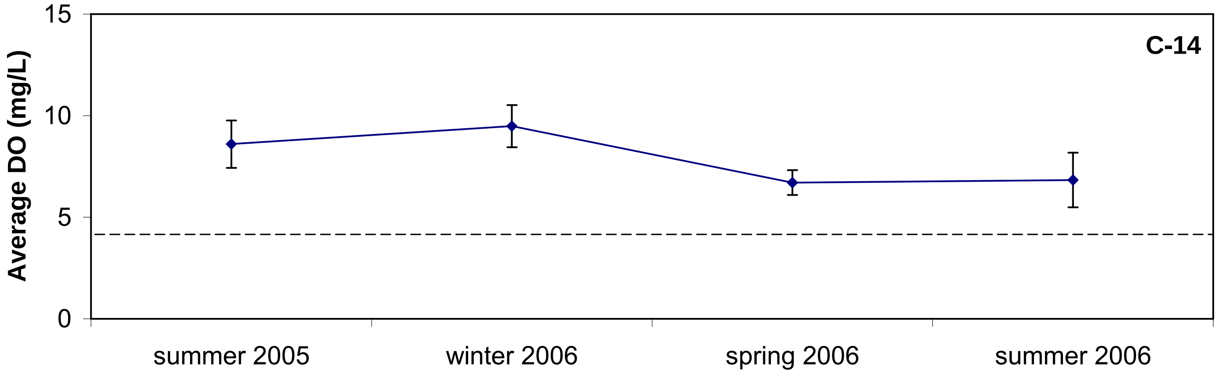

Figure 5-48. Average DO at Location C-14

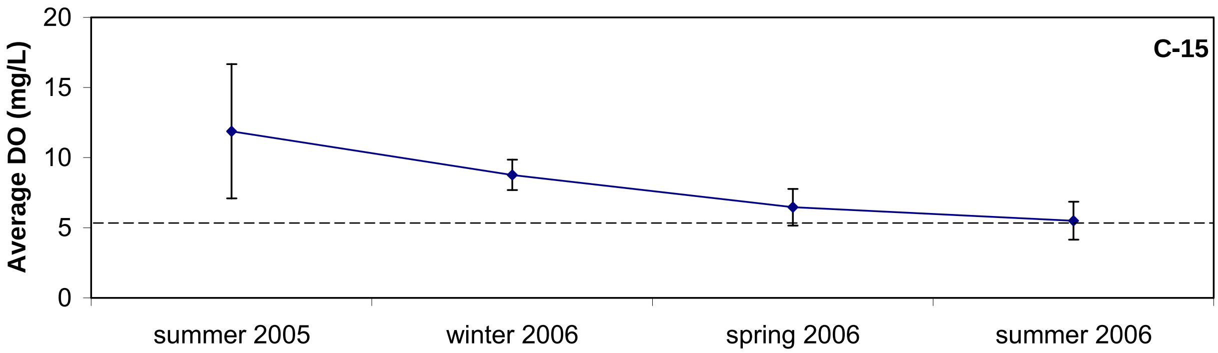

Figure 5-49. Average DO at Location C-15

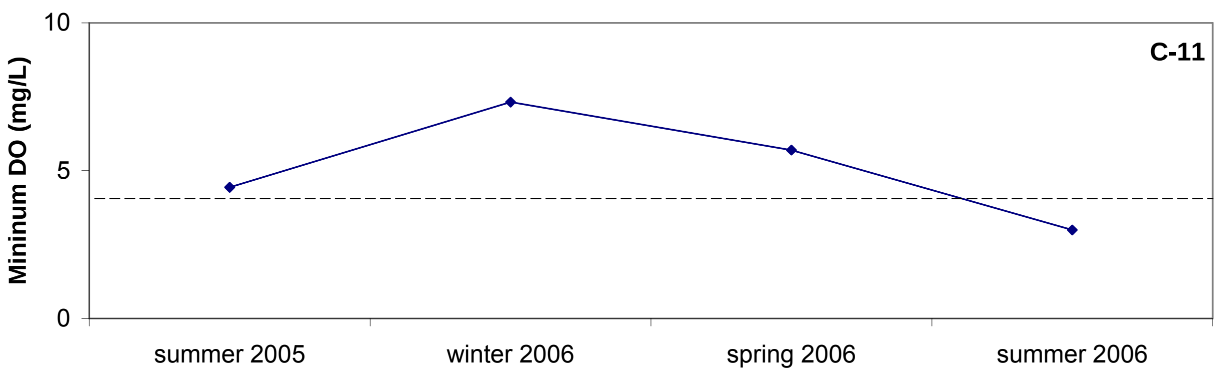

Figure 5-50. Minimum DO at Location C-11

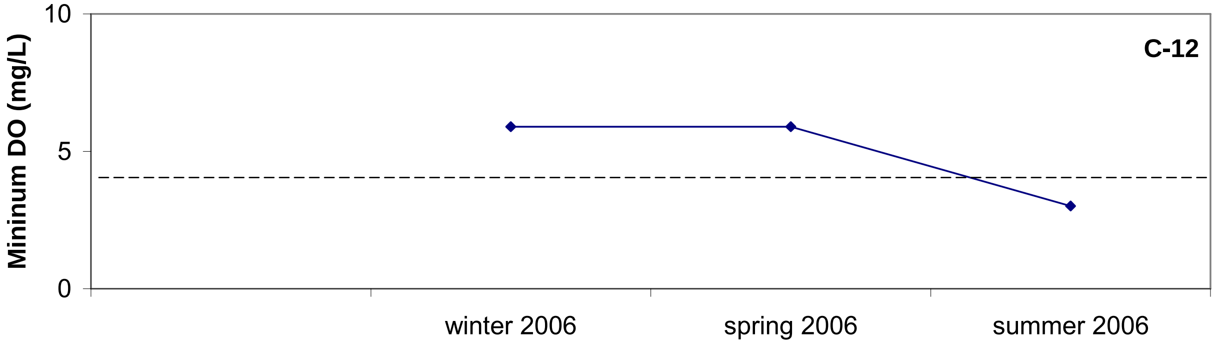

Figure 5-51. Minimum DO at Location C-12

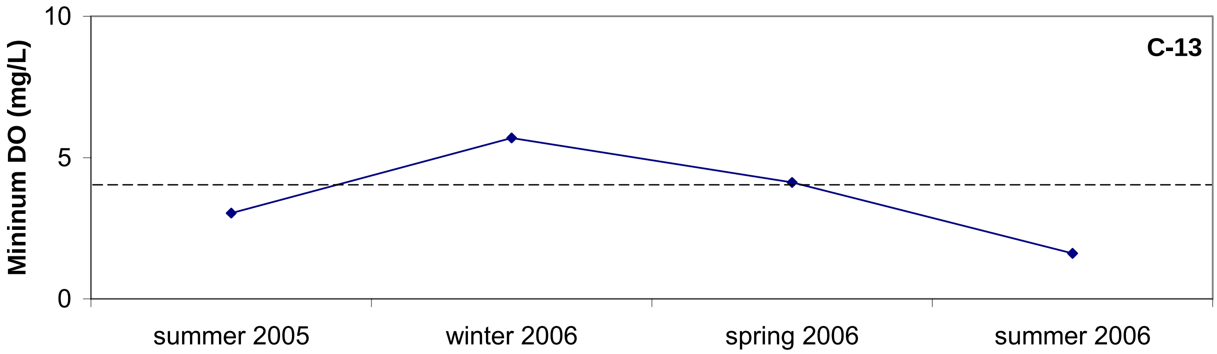

Figure 5-52. Minimum DO at Location C-13

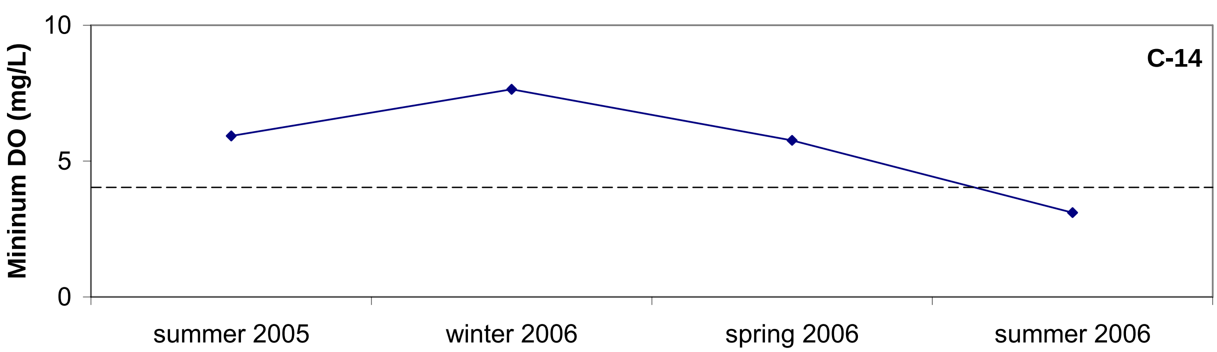

Figure 5-53. Minimum DO at Location C-14

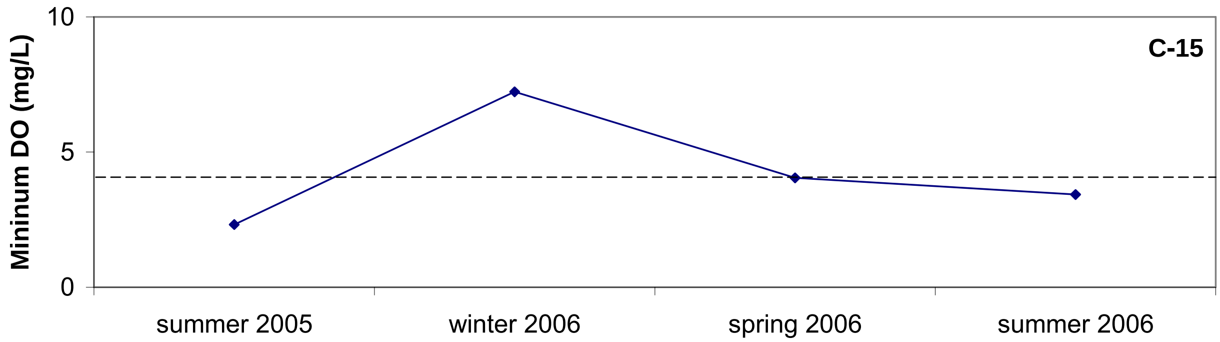

Figure 5-54. Minimum DO at Location C-15

5.2.2 Other Water Quality Parameters

No excursions of the pH water quality standard were observed. Exceedances of the maximum temperature water quality standard only occurred at C-12, C-13, and C-14 during the summer 2006 critical period. Salinity exhibited marked seasonal variability. At all sites, highest salinity occurred during spring 2006. At C-11 and C-12, salinity increased from summer 2005 to winter 2006, peaked during spring 2006, and decreased during summer 2006. At C-13, C-14, and C-15, salinity decreased from summer 2005 to winter 2006, peaked during spring 2006 and decreased during summer 2006. Using 50 NTU as a guideline, turbidity was low at all sites. Although some variability was observed in nitrogen, total phosphorus and other water quality indicator parameters, there was not an indication of significant nutrient loading at the sites.

5.2.3 Habitat Characteristics

Non-forested wetland was the primary surrounding habitat type. Emergent vegetation (*Juncus*/*Spartina* marsh community) was the only type of aquatic vegetation observed. Subtle differences in the percentage of *Spartina patens* were the only discriminating characteristic among these sites.

5.2.4 Benthic Macroinvertebrate Communities

For dip net samples collected in 2006, species richness ranged from 14 to 18 and total number of individuals ranged from 49 to 285 (Table 5-11). Number of benthic invertebrate individuals did not vary significantly among sites (Kruskal-Wallis P=0.7944). Shannon-Weiner diversity was highest at C-11 (3.63) and lowest at C-13 (2.32).

For ponar samples collected in 2006, species richness ranged from 2 to 17 and total number of individuals ranged from 2 to 55 (Table 5-12). Number of benthic invertebrate individuals varied significantly among sites (Kruskal-Wallis P<0.0001). Shannon-Weiner diversity was highest at C-12 (3.50) and lowest at C-15 (1.00).

Table 5-11. Summary of Benthic Macroinvertebrate Analysis of Dip Net Samples Collected from Sites C-11 through C-15, Terrebonne Basin, Louisiana, Summer 2006

Metric	C-11	C-12	C-13	C-14	C-15
Total individuals	147	86	285	152	49
Corrected Abundance	147	86	285	152	49
Number of Species	18	18	18	14	14
Shannon-Weiner Diversity-bits	3.60	3.11	2.32	2.48	2.89
EPT richness	0	0	0	0	0
EPT index	0	0	0	0	0
EPT/EPT Chironomids	NA	NA	0	0	0
Scrapers/Scrapers + Filterers	0	NA	0.5	1	0.5
Hilsenhoff Biotic Index	8.90	9.41	5.42	5.78	5.65

Table 5-12. Summary of Benthic Macroinvertebrate Analysis of Ponar Samples Collected from Sites C-11 through C-15, Terrebonne Basin, Louisiana, Summer 2006

Metric	C-11	C-12	C-13	C-14	C-15
Total individuals	5	55	11	7	2
Corrected Abundance	5	55	11	7	2
Number of Species	3	17	4	4	2
Shannon-Weiner Diversity-bits	1.37	3.50	1.44	1.66	1.00
EPT richness	0	0	0	0	0
EPT index	0	0	0	0	0
EPT/EPT Chironomids	NA	0	0	0	NA
Scrapers/Scrapers + Filterers	NA	0	NA	1	NA
Hilsenhoff Biotic Index	NA	9.38	10	9.17	4

An additional benthic index, the Gulf of Mexico Benthic Index (Engle et al. 1994; Engle and Summers 1999) was calculated for ponar samples of the saltwater sites. Engle and Summers (1999) indicate that a Benthic Index score of 3 or less is ‘Degraded’ and a score greater than 5 attains ‘reference’ condition standards. Index scores between 3 and 5 are ‘unknown’ or intermediate.

Because the total abundance of organisms for these samples are low (site C-15 only has 2 individuals), these results are likely to have high uncertainty. Results of the determination of the Gulf of Mexico Benthic Index are presented in Table 5-13.

Table 5-13. Results of the Gulf of Mexico Benthic Index

Site	C-11	C-12	C-13	C-14	C-15
EcoAnalysts Sample ID	4	6	8	10	12
Species Richness	3	17	4	4	2
Shannon-Weaver H' (log 2)	1.37	3.50	1.44	1.66	1.00
Tubificidae	0	3	2	0	0
Bivalves	0	7	0	0	0
Capitellidae	0	0	0	0	0
Amphipoda	4	0	0	0	0
Total abundance	5	55	11	7	2
Benthic Index	6.8	4.7	3.0	5.5	4.1

In summary, the results of the benthic index indicate that only sites C-11 and C-14 would be considered reference sites, while sites C-12 and C-15 would be categorized as unknown or intermediate condition. Site C-13 would be considered to be degraded, although only 11 organisms were recovered from the sample.

For both dip net samples and ponar samples, bivariate plots of DO concentrations (average and minimum) and benthic species richness and diversity showed no clear biologically significant relationship (Figures 5-55 through 5-62). The lack of relationship is illustrated by benthic species richness being higher at locations with lower DO and locations with higher DO having lower species richness. Similarly, higher benthic diversity was observed at locations with lower DO. Similar results were obtained when plotting discrete measurements of DO collected during the benthic sampling event. Therefore, regression analysis was not evaluated as no biologically significant trend was apparent.

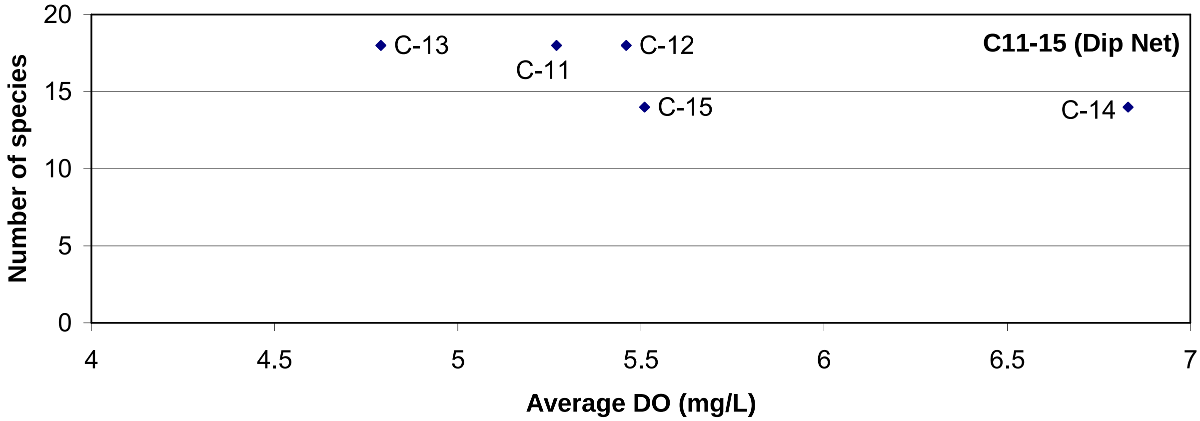

Figure 5-55. Bivariate Plot of Average DO and Benthic Macroinvertebrate Species Richness (Dip Net) at Locations C-11 – C-15, Terrebonne Basin, Louisiana

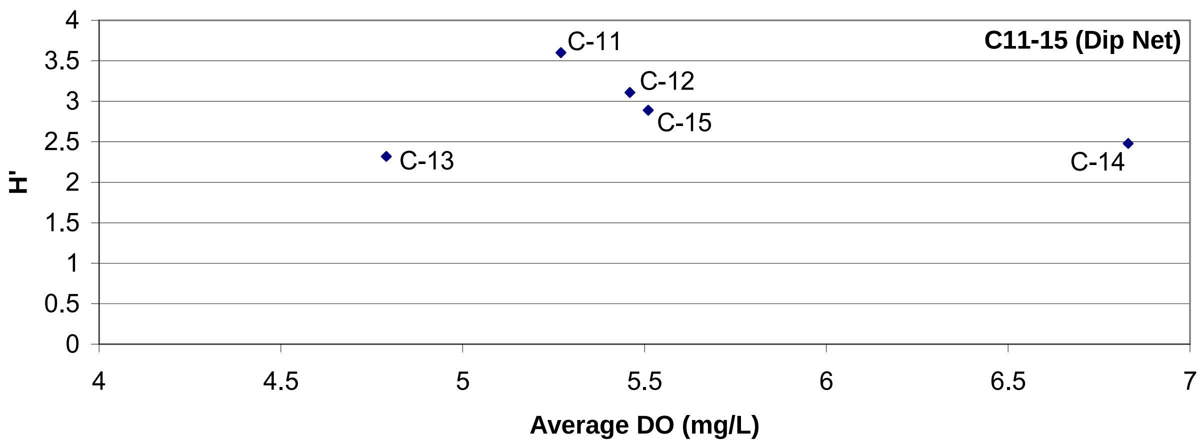

Figure 5-56. Bivariate Plot of Average DO and H' (Shannon-Weiner Diversity Bits) of Benthic Macroinvertebrate (Dip Net) at Locations C-11 – C-15, Terrebonne Basin, Louisiana

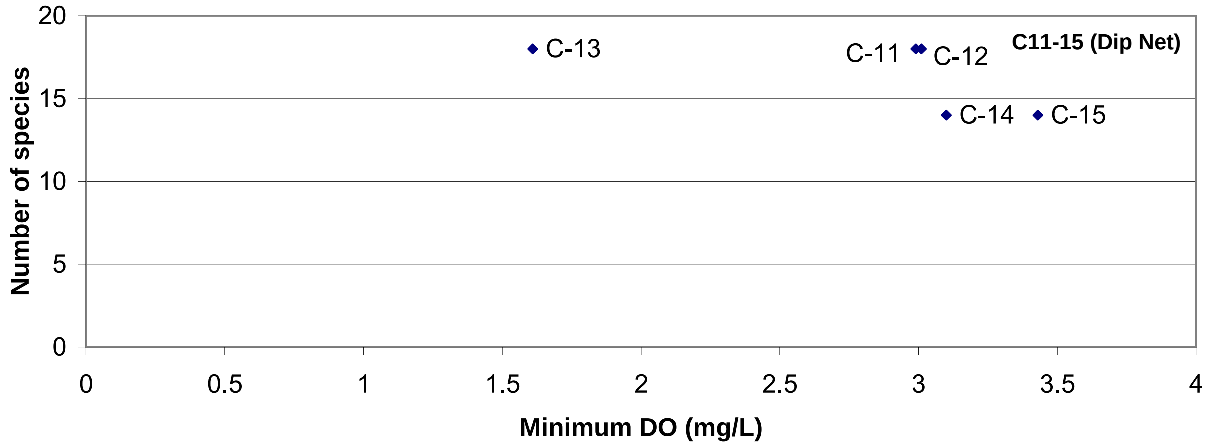

Figure 5-57. Bivariate Plot of Minimum DO and Benthic Macroinvertebrate Species Richness (Dip Net) at Locations C-11 – C-15, Terrebonne Basin, Louisiana

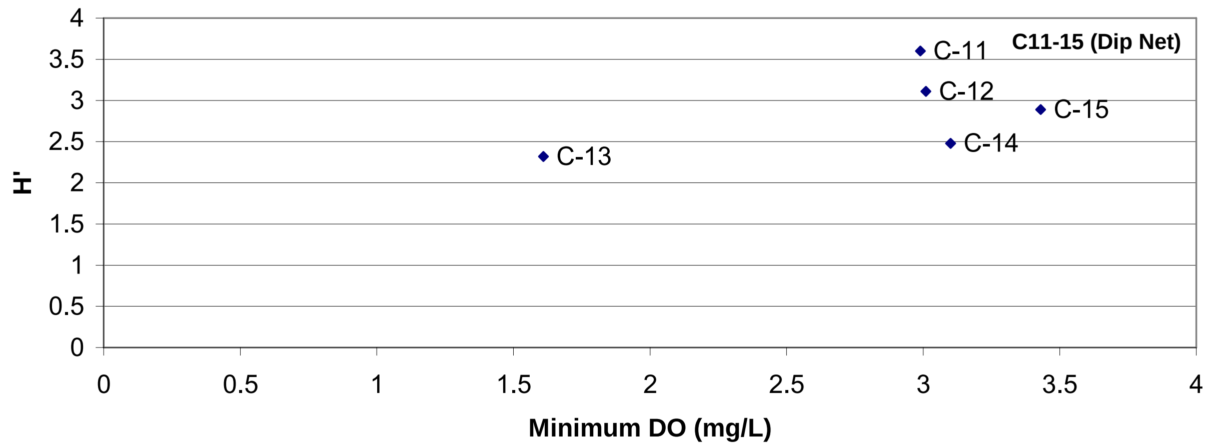

Figure 5-58. Bivariate Plot of Minimum DO and H' (Shannon-Weiner Diversity Bits) of Benthic Macroinvertebrate (Dip Net) at Locations C-11 – C-15, Terrebonne Basin, Louisiana

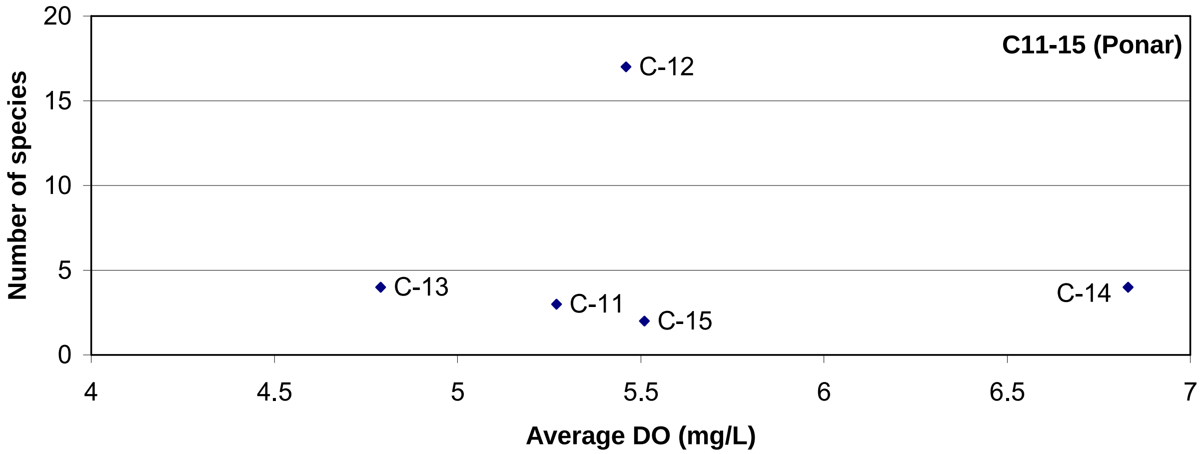

Figure 5-59. Bivariate Plot of Average DO and Benthic Macroinvertebrate Species Richness (Ponar) at Locations C-11 – C-15, Terrebonne Basin, Louisiana

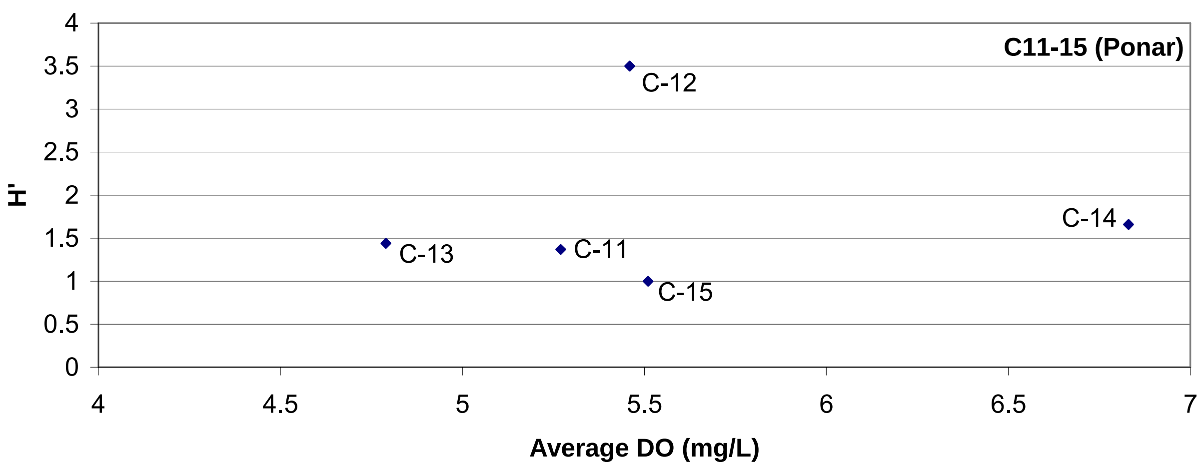

Figure 5-60. Bivariate Plot of Average DO and H' (Shannon-Weiner Diversity Bits) of Benthic Macroinvertebrate (Ponar) at Locations C-11 – C-15, Terrebonne Basin, Louisiana

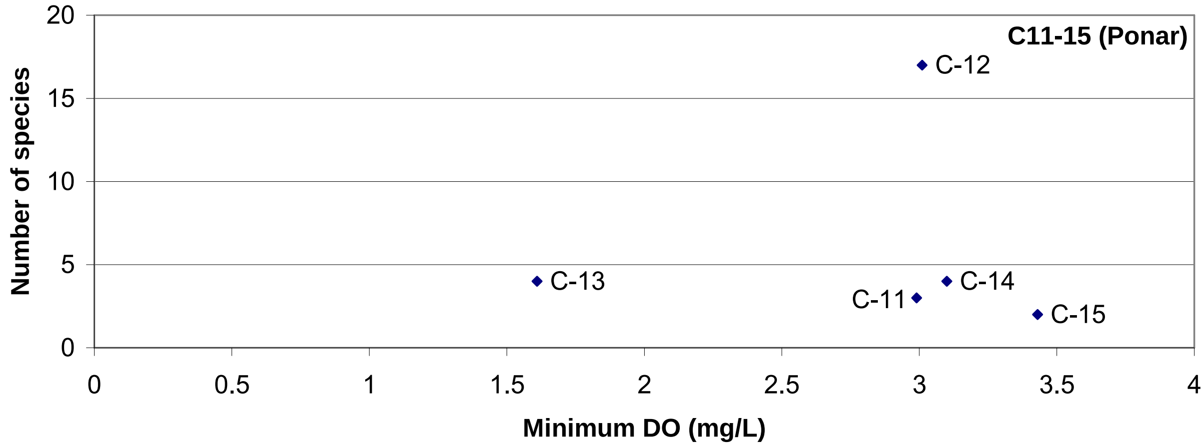

Figure 5-61. Bivariate Plot of Minimum DO and Benthic Macroinvertebrate Species Richness (Ponar) at Locations C-11 – C-15, Terrebonne Basin, Louisiana

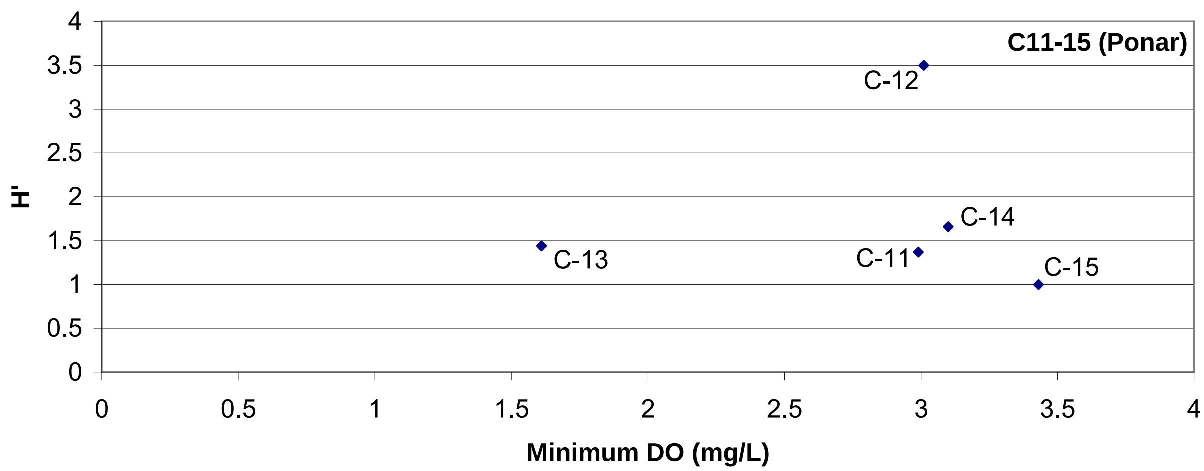

Figure 5-62. Bivariate Plot of Minimum DO and H' (Shannon-Weiner Diversity Bits) of Benthic Macroinvertebrate (Ponar) at Locations C-11 – C-15, Terrebonne Basin, Louisiana

In general, dominant taxa for dip net samples were tolerant taxa such as *Palaemonetes pugio* (grass shrimp), and hydrobiidae (snails) (Appendix I). Dominant taxa for ponar samples were also represented by tolerant taxa such as *Ampelisca* sp. (amphipod), Enchytraeidae (oligochaete), and *Tanypus sp*. (chironomid midge).

5.2.5 Fish Communities

Species richness for fish at the saltwater sites ranged from 9 to 20 and total number of individuals ranged from 104 to 1161 (Table 5-14). Number of individual fish did not vary significantly among sites (Kruskal-Wallis P=0.3010). Shannon-Weiner diversity was highest at C-15 (2.27) and lowest at C-14 (0.61). Bivariate plots of DO concentrations (average and minimum) and fish species richness and diversity showed no clear biologically significant relationship (Figures 5-63 through 5-66). The lack of relationship is illustrated by fish species richness being higher at locations with lower DO and locations with higher DO having lower species richness. Similarly, higher fish diversity was observed at locations with lower DO. Similar results were obtained when plotting discrete measurements of DO collected during the fish sampling event (Figures 5-67 and 5-68). Therefore, regression analysis was not evaluated as no biologically significant trend was apparent.

In general, dominant taxa were bay anchovy, Atlantic croaker, and catfish, see Figures 5-69. Bay anchovy were the most dominant species, comprising from 17 to 92 percent of the fish community.

Based on data from similar species reported by USEPA (2000), the violet goby, southern flounder, chain pipefish, and gulf menhaden would be considered sensitive to low DO. The violet goby was observed at locations C-12, C-13, and C-14. The southern flounder, chain pipefish, gulf menhaden were only observed at C-12. Low species diversity at C-12, C-13, and C-14 is primarily due to the abundance of a single species, bay anchovy. Based on relatively high species richness and the presence of sensitive species, these locations do not appear to be negatively impacted by a low DO regime.

Table 5-14. Summary of Total Individuals, Number of Species, and Shannon-Weiner Diversity of Fish Collected from Locations C-11 to C-15, Terrebonne Basin, Louisiana

Metric	C-11	C-12	C-13	C-14	C-15
Total Individuals	162	1,133	1,161	825	104
Number of Species	9	20	17	12	11
Shannon-Weiner Diversity -Bits	1.84	0.79	0.68	0.61	2.37

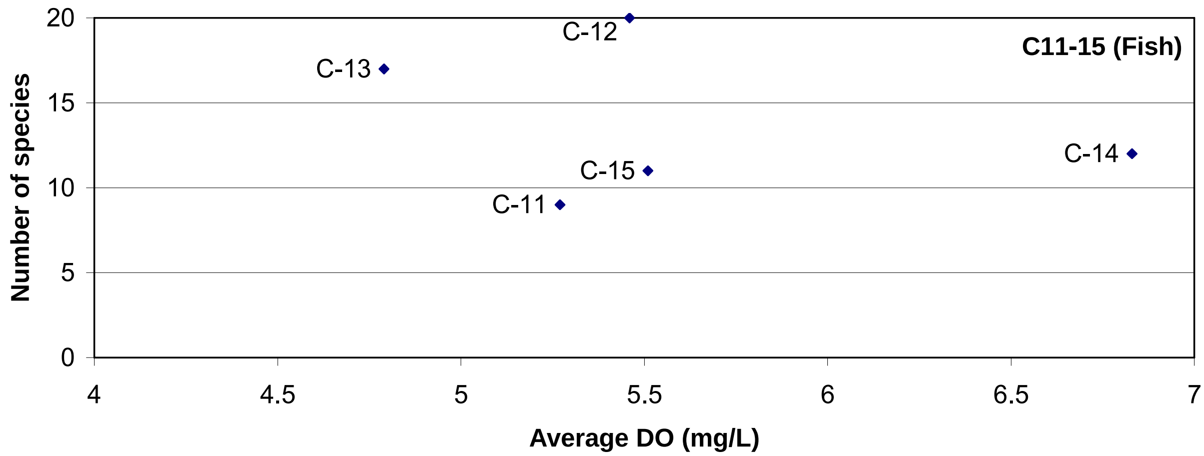

Figure 5-63. Bivariate Plot of Average DO and Fish Species Richness at Locations C-11 – C-15, Terrebonne Basin, Louisiana

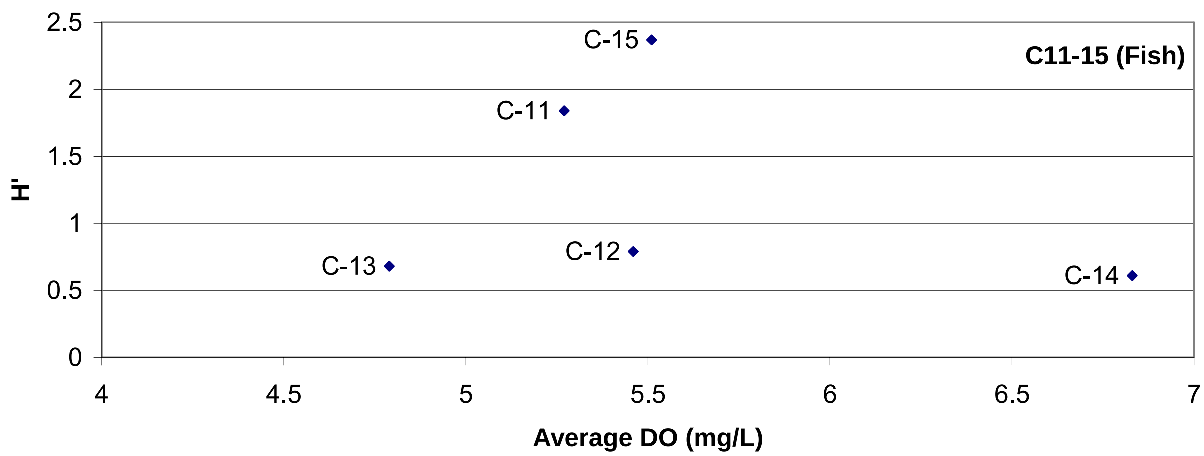

Figure 5-64. Bivariate Plot of Average DO and H' (Shannon-Weiner Diversity Bits) of Fish at Locations C-11 – C-15, Terrebonne Basin, Louisiana

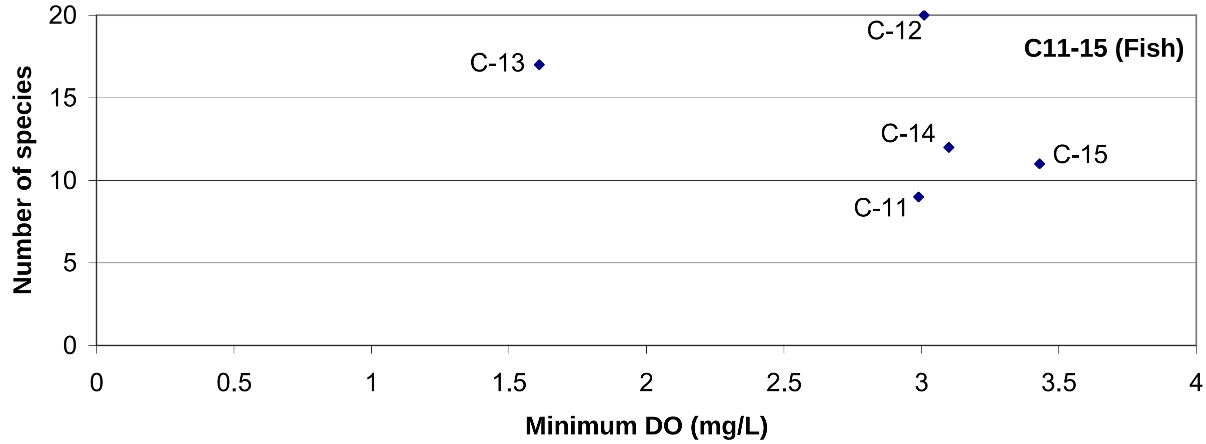

Figure 5-65. Bivariate Plot of Minimum DO and Fish Species Richness at Locations C-11 – C-15, Terrebonne Basin, Louisiana

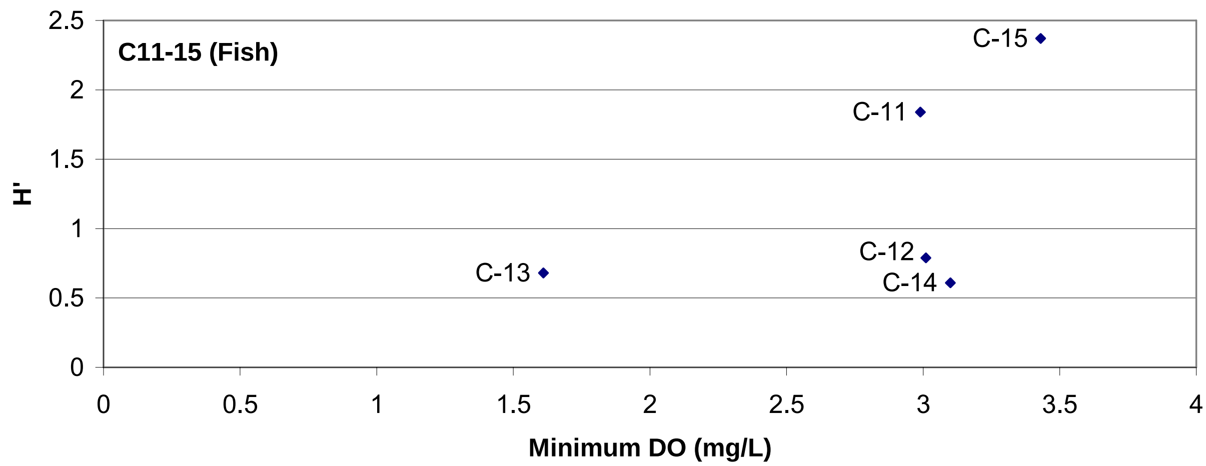

Figure 5-66. Bivariate Plot of Minimum DO and H' (Shannon-Weiner Diversity Bits) of Fish at Locations C-11 – C-15, Terrebonne Basin, Louisiana

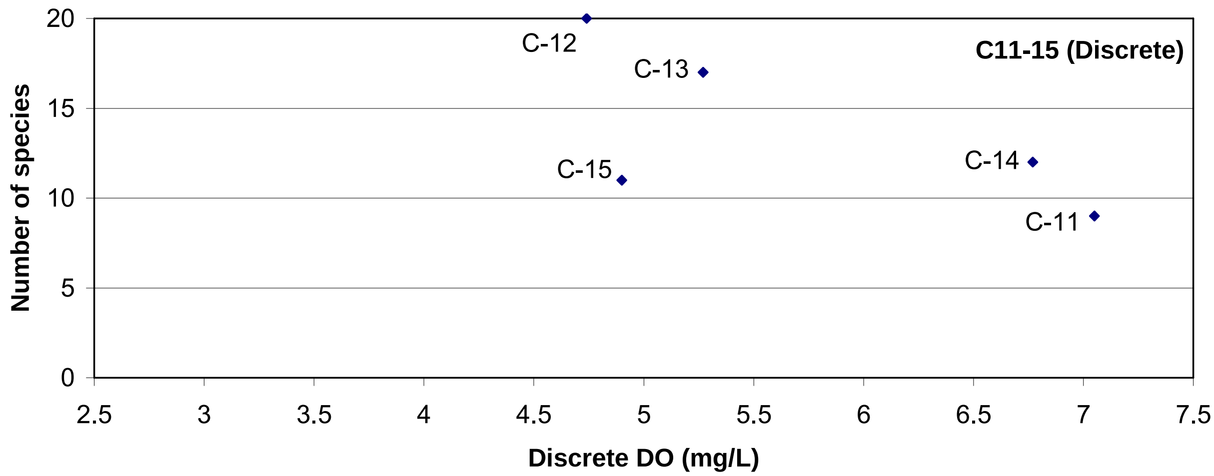

Figure 5-67. Bivariate Plot of Discrete DO and Fish Species Richness at Locations C-11 – C-15, Terrebonne Basin, Louisiana

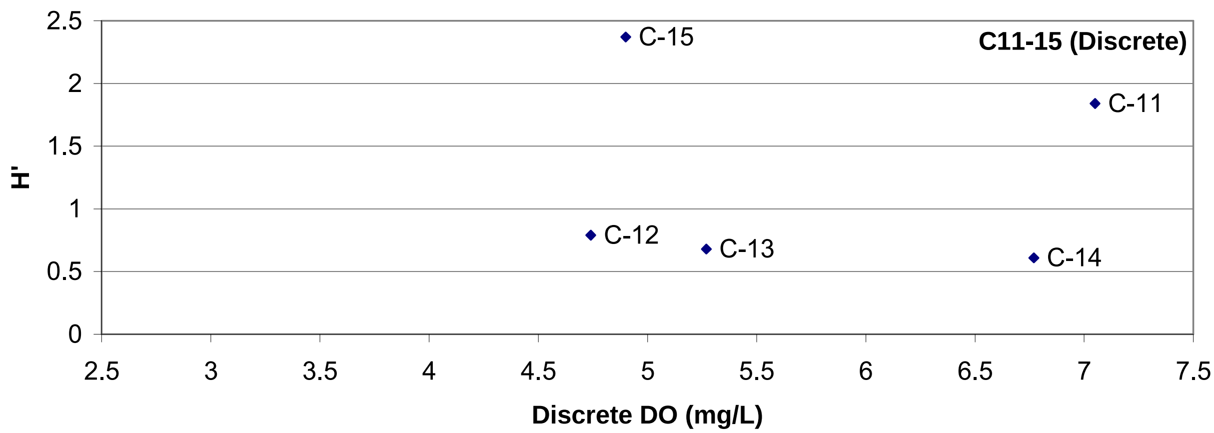

Figure 5-68. Bivariate Plot of Discrete DO and H' (Shannon-Weiner Diversity Bits) of Fish at Locations C-11 – C-15, Terrebonne Basin, Louisiana

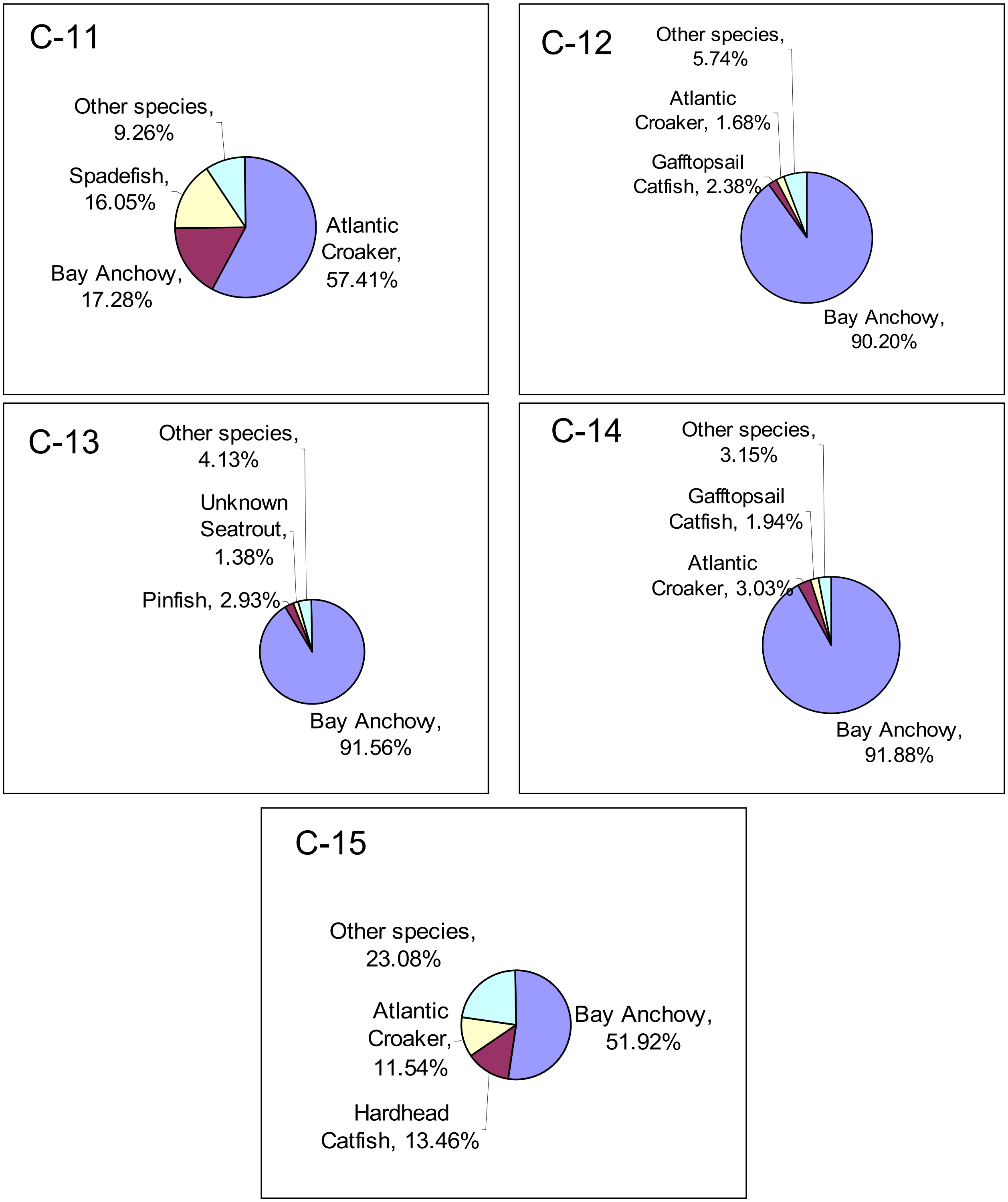

Figure 5-69. Dominant Fish Species at Sites C-11 through C-15

5.3 Historical DO Data

Historical DO data were obtained from three sources: The USEPA Environmental Monitoring and Assessment Program (EMAP), USEPA Region 6 (provided to Region 6 by LDEQ), and the Louisiana Department of Wildlife and Fisheries (LDWF) Inland Fisheries Division. Only the nearest monitoring stations to the reference sites in this study were selected for comparison.

The USEPA EMAP database provided discrete measurements of DO from 13 station locations that are adjacent to locations C-6, C-7, C-9, and C-11 through C-15 (Table 5-15). The sampling periods for the data presented in the EMAP database were July through September of 1991, 1992, 1993, and 1994. As shown in Table 5-15, DO measurements from stations adjacent to mixed salinity sites C-6, C-7, and C-9 ranged from 1.8 mg/L to 11.3 mg/L. DO measurements from stations adjacent to saltwater sites C-11 through C-15 ranged from 5.0 mg/L to 6.6 mg/L. With the exception of the DO measurement from Station LA91SR39 (1.8 mg/L), all other discrete DO measurements were greater than the LDEQ DO standards of 5.0 mg/L for freshwater and 4.0 mg/L for estuarine/marine waters. Because these data represent discrete measurements, they are of limited relevance for comparing with the averages and minimum DO values obtained over the 48-hour recording periods for the Terrebonne basin investigation.

Table 5-15. Historical DO Data from USEPA Environmental Monitoring and Assessment Program (EMAP)

Site	Adjacent Historical Data Station Name	DO (mg/L)	Sampling Period
C-6	LA92SR21	6.5	July-Sep 1992
	LA91SR39	1.8	July-Sep 1991
C-7	LA91SR17	11.3	July-Sep 1991
C-9	LA91SR17	11.3	July-Sep 1991
C-11	LA92SR23	5.0	July-Sep 1992
	LA92SR18	6.0	July-Sep 1992
	LA94SR20	6.6	July-Sep 1994
	LA94SP20	6.5	July-Sep 1994
C-12	LA92SR18	6.0	July-Sep 1992
C-13	LA93SR17	6.0	July-Sep 1993
C-14	LA92SR19	5.6	July-Sep 1992
C-15	LA92SR19	5.6	July-Sep 1992
	LA93SR17	6.0	July-Sep 1993

The DO data provided to USEPA Region 6 by LDEQ were collected from sampling stations in the vicinity of locations C-1, C-4, C-6, C-8, and C-10 through C-15 (Table 5-16). The data were collected between 1998 and 2005. With the exception of LDEQ stations 0114 and 0350, data from all stations were collected during all four seasons (i.e., spring, summer, fall, winter). Average DO measurements from the LDEQ stations located near freshwater sites C-1 and C-4 ranged from 4.32 mg/L to 7.04 mg/L, while minimum DO measurements ranged from 1.09 mg/L to 5.93 mg/L. The LDEQ findings are similar to those obtained during this investigation. Average DO measurements from the LDEQ stations located near mixed salinity sites C-6, C-8, and C-10 ranged from 2.49 mg/L to 6.38 mg/L, while minimum DO measurements ranged from 0.62 mg/L to 6.84 mg/L. In the study reported herein, the average DO value at the mixed salinity sites was not as low, but the range in minimum DO was broader than that found by LDEQ. Average DO measurements from the LDEQ stations located near saltwater sites C-11 through C-15 ranged from 5.34 mg/L to 8.73 mg/L, while minimum DO measurements ranged from 4.71 mg/L to 8.2 mg/L. The LDEQ results are comparable to those obtained in the study reported herein.

Discrete DO data at LDWF freshwater fish sampling stations were obtained in the vicinity of Locations C-6 and C-9 (Table 5-17). The data provided by LDWF were collected between 2004 and 2006 during all seasons. DO at these stations ranged from 5.28 to 13.57 mg/L which are all above the applicable LDEQ DO standard of 5 mg/L. Because these data represent discrete sampling points, they are not directly comparable to the average and minimum values obtained during this investigation.

5.4 Historical Benthic Macroinvertebrate Data

Although no historical benthic macroinvertebrate data were located for the Terrebonne Basin, a number of studies have been conducted in the nearby Barataria Basin.

Vittor and Associates, Inc. (1995) conducted a 14-year survey of the benthic infauna from a low-salinity and high salinity area in the Barataria estuary, Louisiana. High variation in the number of taxa and density was found both seasonally and annually. Dominant taxa at both locations included annelid worms (oligochaetes and polychaetes), mollusks (bivalves), and arthropods (luciculous amphipods and chironomids). At the low salinity zone, which would be comparable to sites C-11 through C-15, dominant taxa were the oligochaete worms, *Mediomastus, Streblospio*, and *Hobsonia* (polychaete worms); the family Chironomidae (midges) and *Corophium* and *Grandidierella* (amphipods). In addition to salinity effects, populations appeared to be structured by sediment grain size with coarser sediments correlated with an increase in the proportion of arthropods to annelid worms and mollusks (Vittor and Associates, Inc. 1995).

Table 5-16. Historical DO data from Louisiana Department of Environmental Quality's routine monitoring for the Terrebonne Basin, Louisiana

Site	Closest LDEQ Station	Sampling Period	Season	Average DO (mg/L)	Minimum DO (mg/L)
C-1	0336	02/1998-11/2004	Jan-Mar	6.29	2.52
			April-Jun	4.34	3.2
			Jul-Sep	4.51	1.09
			Oct-Dec	4.54	2.05
C-4	0973	02/2000-11/2004	Jan-Mar	7.04	3.43
			April-Jun	5.47	1.40
			Jul-Sep	4.32	2.25
			Oct-Dec	6.17	5.93
C-6	0980	01/2000-08/2005	Jan-Mar	5.57	4.48
			April-Jun	3.66	2.08
			Jul-Sep	2.49	0.62
			Oct-Dec	2.74	2.55
C-8	0144	01/2000-08/2005	Jan-Mar	7.52	6.00
			April-Jun	6.38	3.11
			Jul-Sep	5.37	2.7
			Oct-Dec	4.81	2.77
C-10	0114	01/1998-02/1995	Jan-Mar	6.32	4.5
			April-Jun	–	6.84
C-11, C-12	0951	01/2000-11/2000	Jan-Mar	7.60	7.03
			April-Jun	6.38	5.72
			Jul-Sep	6.21	5.78
			Oct-Dec	7.34	6.59
C-13	0948	01/2000-08/2005	Jan-Mar	8.73	7.1
			April-Jun	6.71	5.46
			Jul-Sep	5.34	4.71
			Oct-Dec	8.07	7.07
C-14, C-15	0350	02/1998-04/1998	Jan-Mar	–	8.2
			April-Jun	–	7.1

For comparison purposes, only the nearest monitoring stations to the reference sites in this study are selected. LDEQ DO monitoring data were not available near Sites C-2, C-3, C-5, C-7, and C-9.

Table 5-17. Historical Water Quality Data for Fish Sampling by LDWF, Terrebonne Basin, Louisiana, 2004-2006

Site	Station	Month	Day	Year	Oxygen (Top)	Temp (Top)	pH (Top)	pH (Bottom)
C-9	5	4	12	2006	8.01	23.30	6.37	7.05
C-9	5	4	21	2004	8.47	23.60	7.10	8.00
C-9	5	4	28	2005	8.97	23.40	6.34	7.64
C-9	5	11	1	2005	9.48	18.97	6.16	6.75
C-9	5	11	14	2006	10.36	18.24	8.08	8.18
C-9	5	11	15	2004	10.34	17.64	5.68	6.40
C-6	8	4	27	2004	7.79	24.79	7.66	7.51
C-6	8	5	11	2005	10.68	28.22	8.76	8.67
C-6	8	11	2	2005	9.65	18.38	6.01	6.21
C-6	8	11	20	2006	5.88	14.53	6.95	7.02
C-6	43	7	28	2005	6.65	31.60	7.80	7.90
C-6	43	8	5	2005	5.28	29.20	7.55	7.37
C-6	44	7	29	2005	6.81	30.62	6.65	6.85
C-6	44	8	4	2005	6.77	30.21	7.62	8.16
C-9	61	1	23	2006	13.57	18.24	7.93	7.96
C-9	61	2	2	2005	11.11	13.03	6.43	6.61
C-6	62	1	31	2006	11.98	15.46	7.76	7.83
C-6	62	3	22	2005	10.58	22.80	6.28	6.74

For comparison purposes, only the nearest monitoring stations to the reference sites in this study is selected.

A detailed summary of the benthic communities and related research that has been conducted in the adjacent Barataria Basin is presented in Conner and Day (1987). A two year survey by Sklar (1983) of three swamp sites in the upper basin reported 66 taxa of aquatic invertebrates. Seventeen taxa of invertebrates averaged over 100 individuals/m^2 and included one amphipod and a dipteran which averaged over 1,000 individuals/m^2. However, 44 percent of the taxa averaged fewer than 10 individuals/m^2. Similar variability in population density was observed for both the 2005 and 2006 benthic data in the present study. Floating vegetation populations had significantly greater densities of Amphipoda, Coleoptera, Diptera, Ephemeroptera, Gastropoda, Hemiptera, Hydroidia, Lepidoptera, Odonata, and Tricladida than sediment habitats. Results of the present study also demonstrated that dipnet sample abundance was substantially higher than ponar sample abundance. A bimodal seasonal distribution of benthos in the swamp habitats was observed with an early summer peak and an autumn peak. A decrease in population densities in late summer was attributed to swamp hydrology (e.g., drying out period) and anoxic conditions resulting from release of hydrogen sulfide and natural organic inputs (Sklar 1983).

Physical factors that have been shown to affect the benthic community in the Barataria Basin include salinity, sediment type, and dissolved oxygen (Conner and Day 1987). An example of the effects of sediment type was observed at site C-9 in the present study where a high clay substrate and low TOC correlated with the least diverse benthic community. Very low dissolved oxygen conditions in shallow estuarine systems were not reported to persist long enough to substantially limit benthic communities. Historical dissolved oxygen data from 1948 (1,134 measurements) from all parts of the greater Barataria Bay area indicated that 49% of all oxygen measurements fell between 5 and 6 ppm and only three measurements showed oxygen levels below 2 ppm, and none below 1.5 ppm. Factors such as sediment type and water current were reported to substantially change the composition of benthic communities. Salinity appears to be the most important factor in determining bottom community composition in estuarine systems (Conner and Day 1987).

A comprehensive benthic invertebrate study (32 stations from freshwater to saline habitats, each sampled once) of the Barataria basin was conduced by Philomena (1983). A total of 94 species of invertebrates were collected. Dominant taxa were crustaceans, polychaetes, oligochaetes, nematodes, and insects which represented approximately 90% of all organisms collected. Abundance of organisms was highest in stations near the marsh edge and in shallow bayous, and higher in freshwater sites than saline sites (Philomena 1983). Shannon-Weiner diversity of the 32 stations was similar to the typical pattern of species richness versus salinity (high number of species in freshwater to oligosaline, lowest numbers of species for mesosaline areas, and higher number of species towards polysaline areas). Mean diversity values were 1.64 for the freshwater to oligohaline areas, 1.135 for mesohaline areas, and 1.167 for polysaline areas (Philomena 1983). Similar dominant taxa and pattern of species richness was observed at sites C-1 through C-15 in the Terrebonne Basin. Lower species richness occurred at saltwater sites C-11 through C-15 than at freshwater and mixed sites C-1 through C-10.

Despite these reported studies, the seasonal composition, abundance, and distribution of benthos of the Barataria Basin remains poorly understood. Although the benthos of the Terrebonne Basin has not been as well studied as the Barataria Basin, it is likely that similar ecological patterns would exist for benthos. Much confusion regarding the apparent seasonal abundance of benthos being lower in summer and higher in winter has led to speculation about low dissolved oxygen in the warmer months. However, this speculation may be a result of interpretation of studies in freshwater ponds and lakes where stratification and complete oxygen depletion in bottom water are common (Conner and Day 1987).

This is not the case for the shallow, tidally-mixed estuarine habitats in the Barataria Basin or the Terrebonne Basin where wind is often the predominant force. Oxygen depletion to the point of defaunation of benthos is unlikely except in stagnant dead-end canals (Conner and Day 1987).

5.5 Historical Fish Data

Historical fish data were obtained from the LDWF (Appendix M) and published literature. For comparison purposes, historical data were selected based on proximity to the reference sites, critical season, and similarity of collection methods. Sampling stations were plotted on the map of the fifteen reference sites used for this study and the nearest sampling stations were selected for each reference location (when available). For some reference sites, no LDWF stations were nearby. Data for the selected station was then further screened by sampling date and collection method, with preference given to date collected (e.g., summer season, from July to September) and similarity of collection method to this study.

Table 5-18 summarizes the freshwater fish data obtained from LDWF for 2004-2006. Species richness ranged from 7 to 25 and total number of individuals ranged from 45 to 2126. Shannon-Weiner diversity was highest near site C-6 and lowest near site C-9. Similar species were observed when comparing the electrofishing data from the present study with that of LDWF (Appendix M). However, results from the rotenone sampling yielded higher species richness and diversity when compared to the present study. Appendix M lists all species recorded by LDWF used to calculate species richness and diversity. This represents sampling method differences where sampling with rotenone typically yields higher number of species.

Tables 5-19 and 5-20 summarize the LDWF saltwater fish data for 2004 and 2006, respectively. For 2004, species richness ranged from 4 to 12 and total number of individuals ranged from 13 to 308. Shannon-Weiner diversity ranged from 0.3 to 2.9. For 2005 and 2006, species richness ranged from 5 to 15 and total number of individuals ranged from 15 to 1,367. Shannon-Weiner diversity ranged from 1.2 to 2.4. Species richness and diversity of saltwater fish reported for the present study was comparable to the results of the LDWF data. However, some differences in species composition observed are likely due to the sampling method differences (Appendix M). For example, LDWF seine samples yielded small species of fish such as *Fundulus* spp.).

Freshwater fish collected from sites C-1 through C-10 in the present study were similar to those reported for freshwater fish in the adjacent Barataria Basin (Conner and Day 1987). A total of 31 species of freshwater fish have been reported for the Barataria Basin. Largemouth bass and channel catfish are utilized as freshwater fish indicators species by LDWF. Long-term population abundance data from Lake Verret suggest that these species are stable (Barataria-Terrebonne National Estuary Program 2002).

Saltwater fish (9 – 20 species) collected from sites C-11 through C-15 in the present study represent fish that are primarily estuarine-marine and marine in their ecological affinity and are most comparable to the 26 species of estuarine-marine forms reported for the entire Barataria Basin (Conner and Day 1987). Based on trawl data, the 10 most abundant species were bay anchovy, Atlantic croaker, Atlantic bumper (*Chloroscombis chrysurus*), Gulf Menhaden, spot, hardhead catfish, sand seatrout, Atlantic threadfin (*Polydactylus octonemus*), striped anchovy (*Anchoa hepsetus*), and gafftopsail catfish. Overall, the fish fauna of the Barataria Basin was considered to be very high in similarity to the Terrebonne Basin (Conner and Day 1987).

Bay anchovy and Atlantic croaker were the dominant saltwater fish species in the present study and are the most dominant fish species in coastal Louisiana, including the Barataria-Terrebonne Estuary System (BTES). Available data suggest that the populations of the two indicator species appear to be stable although high year to year variability in abundance of both species occurs (Barataria-Terrebonne National Estuary Program 2002). Similarly, recreationally important species such as red drum and spotted seatrout population in the BTES are probably stable.

Table 5-18. Summary of Freshwater Fish Data Collected by LDWF, Terrebonne Basin, Louisiana, 2004-2006

Site	Adjacent Historical Data Station Name	Sampling Date	Collection Method	Total Individuals	Number of Species	Shannon-Weiner Diversity-Bits
C-9	5	11/14/2006	Electrofishing, DC, prod, day , 900 sec Electrofishing, Forage , 180 sec	147	8	2.0
	61	3/9/2004	bar mono gill, 14 hrs	69	8	2.2
	61	2/2/2005	bar mono gill, 15 hrs	116	7	1.2
	61	1/24/2006	bar mono gill, 13 hrs	123	12	2.3
C-6	43	7/27/2005	Rotenone, 1 acre	981	23	2.6
	43	7/28/2005	Rotenone, 1 acre	2,126	17	2.2
	43	8/4/2005	Rotenone, 1 acre	1,120	20	3.0
	43	8/5/2005	Rotenone, 1 acre	240	14	2.8
	44	7/28/2005	Rotenone, 1 acre	800	25	3.1
	44	7/29/2005	Rotenone, 1 acre	589	15	2.0
	44	8/3/2005	Rotenone, 1 acre	913	25	3.1
	44	8/4/2005	Rotenone, 1 acre	2,111	21	2.8
	62	3/23/2004	bar mono gill, 14 hrs	53	9	2.3
	62	3/23/2005	bar mono gill, 17hrs	45	8	2.4
	62	1/31/2006	bar mono gill, 13 hrs	64	12	2.2

For comparison purposes, only the nearest monitoring stations to the reference sites in this study are selected. Fish data are only available for stations near C-6 and C-9.

Table 5-19. Summary of Saltwater Fish Data Collected by LDWF, Terrebonne Basin, Louisiana, 2004

Site	Adjacent Historical Data Station Name	Sampling Date	Collection Method	Total Individuals	Number of Species	Shannon-Weiner Diversity-Bits
C-13	NA	7/15/2004	Gill net	23	9	2.8
		7/29/2004		25	8	1.8
		8/5/2004		32	4	1.1
		8/25/2004		13	7	2.2
		9/3/2004		14	6	2.0
		9/22/2004		23	6	2.2
C-14, C-15	544	7/13/2004	Seine	66	11	2.9
		8/26/2004		243	5	0.3
		9/8/2004		308	9	0.6
		9/21/2004		34	9	2.0
C-14	545	7/13/2004	Seine	192	12	2.5
		8/26/2004		213	10	1.6
		9/27/2004		18	4	1.5

NA = not available

For comparison purposes, only the nearest monitoring stations to the reference sites in this study are selected.

Table 5-20. Summary of Saltwater Fish Data Collected by LDWF, Terrebonne Basin, Louisiana, 2006

Site	Adjacent Historical Data Station Name	Sampling Date	Collection Method	Total Individuals	Number of Species	Shannon-Weiner Diversity-Bits
C-13	NA	7/13/2006	Gill net	15	7	2.3
		7/27/2006		41	8	2.1
		8/4/2006		22	7	2.2
		8/18/2006		15	5	1.8
		9/11/2006		33	8	2.4
		9/20/2006		57	11	2.1
C-14, C-15	544	7/18/2006	Seine	290	12	1.4
		8/9/2005		1367	15	1.2
		9/14/2006		231	11	1.4
		9/26/2006		53	12	2.5
C-14	545	7/18/2006	Seine	137	11	2.0
		8/9/2005		96	6	1.4
		9/14/2006		75	6	2.0
		9/26/2006		70	7	1.7

NA = not available

For comparison purposes, only the nearest monitoring stations to the reference sites in this study are selected.

Deegan and Thompson (1985) described the ecology of estuarine fish communities in the Mississippi River deltaic plain, including Barataria Bay and Fourleague Bay. Although a total of 208 fish species were recorded from the estuaries, the fish community is dominated by a few forms that migrate inshore to use the marsh as a nursery. Using trawl sampling, the top five abundant species included Gulf Menhaden, Atlantic croaker, bay anchovy, sand seatrout, and hardhead catfish. With the exception of Gulf Menhaden, similar species were abundant in trawl samples in the present study. Gulf Menhaden were not abundant during the present study (conducted during August) which is likely explained by the peak seasonal abundance of the species during April (Deegan and Thompson 1985). Shallow marsh areas and the average mid-salinity zone were identified as important location within the estuary. Although seasonal variation in fish community structure was reported, species diversity parameters did not exhibit seasonal trends because of species compensation (seasonal replacement of species related to the salinity cycle).

Plunket and La Peyre (2005) reported a total of eighteen species of fishes from nine families (413 individuals) in gill net sets in Barataria Bay. Gulf menhaden, black drum, and hardhead catfish were dominant species. Salinity during the study averaged 12.6 ± 7.1 (range 4.3 – 22.1) and dissolved oxygen averaged 5.9 ± 3.0 (range 3.3 – 10.2).

5.6 Summary

Excursions of the 5 mg/L DO standard (applicable to the freshwater and mixed sites) during the critical period were widespread among the ten reference sites during the study. Excursions of the 4 mg/L DO standard (applicable to the saltwater sites) occurred less frequently. Concurrent benthic and fish community data indicate that species richness and diversity of biological communities does not appear to be significantly impacted by a low DO regime. This conclusion is supported by the review of historical biological data. The lack of correlation between DO and biological communities supports this apparent lack of effect. Typically, DO and biological species richness and diversity are correlated when evaluating extremes of DO values. In the present study, extremely low (<1 mg/L) values were not typically recorded. Therefore, none of the sites under study are representative of the lower extreme of DO values and this likely contributed to the lack of correlation.

Additional considerations that might explain some of the variability observed in the DO comparisons with biological communities are the duration that DO was depressed during the critical period and the actual lowest concentration of DO reached. At the freshwater and mixed sites, DO concentrations were below 5 mg/L for an average of 26.75 to 39.05 hours. The maximum duration of consecutive exposure to DO less than 5 mg/L was an average of 12 to 21 hours. Although this is a considerable amount of time, fish species are capable of moving into different microhabitats and likely do so in response to changes in water quality. Some preliminary observations made during the fish electroshocking indicate that typically the shaded side of water bodies produced more species and numbers of fish, especially those species (centrarchids) more sensitive to DO. At the saltwater sites, DO concentrations were below 4 mg/L for an average of 9.3 to 10.9 hours which is considerably less time than the freshwater and mixed sites. The maximum duration of consecutive exposure to DO less than 4 mg/L was an average of 0.5 to 5 hours.

The cumulative distribution function (CDF) approach was used to evaluate the percentage of time that DO values were below the applicable DO criterion during the critical period. The percent of time that freshwater and mixed sites were below 5 mg/L was 2 to 75 percent during summer 2005 and 35 to 91 percent during summer 2006. The percent of time that saltwater sites were below 4 mg/L was 0 to 7 percent during summer 2005 and 5 to 43 percent during summer 2006. Additionally, the CDF was used to define the total percent of time (across all sites) which were below the applicable DO criterion. At the freshwater and mixed sites, the average DO, across all ten sites, was below the 5 mg/L standard 55 and 75 percent of the time for summer 2005 and summer 2006, respectively. At the saltwater sites, the average DO was always above the 4 mg/L standard in summer 2005 and 2006. At the freshwater and mixed sites, the minimum DO, across all ten sites, was below the 5 mg/L standard 100 percent of the time for summer in both years. At the saltwater sites, the minimum DO was below the 4 mg/L standard 58 and 100 percent of the time, for summer 2005 and summer 2006, respectively. These results indicate that strict attainment of the DO standard as a minimum value never to be exceeded at any time is not possible at reference sites in the Terrebonne basin.

In general, DO concentrations were maintained above 2 mg/L; therefore, actual hypoxic conditions were rarely observed. Based on the biological data which suggests reasonably diverse and healthy communities when compared to available historical data, factors such as duration of low DO exposure and minimum concentration appear to be important.

Habitat characteristics appear to have affected the biological community at locations C-1, C-3 and C-9. Poor quality habitat at these locations was reflected by the lower fish species richness and diversity at these sites. Benthic invertebrate data were more variable with only ponar samples reflecting poor quality habitat only at site C-9.

Although HBI values for the benthic macroinvertebrate community (freshwater and mixed sites) indicate poor and very poor water quality, general community measures of species richness and diversity appear to be representative of typical benthic communities in south Louisiana. This finding also suggests that widely used benthic community metrics may not be well suited for evaluations of specific stressors such as DO.

6. Proposed Approaches to Refinement of DO Criteria

The current study was conducted using sites that were determined to be reference sites, and therefore, the results provide data on the natural variability of DO and the biological communities that exist within reference conditions. Based on an integration of the physical, chemical and biological data collected during this study, it appears that alternative DO criteria may be suitable for water bodies in the Terrebonne basin.

Several approaches (or combinations thereof) may prove useful for possible refinement of DO criteria for the Terrebonne basin. These include:

- Use of laboratory data as a basis for the DO standard, with field verification
- Definition of a lower DO standard, potentially time dependent, based upon existing data
- Utilization of biological assessment data to determine attainment of DO criteria including selection of indicator species and development of a biological index sensitive to DO
- Development of tiered aquatic life uses and corresponding DO criteria

Each of these approaches is discussed below.

6.1 Laboratory-based Criteria

The traditional approach to derivation of ambient water quality criteria is to use data from laboratory tests with representative aquatic organisms to estimate the concentrations of the pollutant that would not result in acute or chronic adverse effects (EPA, 1985). A modification of this approach was used to develop the saltwater dissolved oxygen criterion for the Virginian Province (EPA, 2000). The approach considered exposures that were both continuous (> 24 hours) and diel (< 24 hours but potentially repeated for days). The limit derived to be protective of juvenile and adult survival from persistent exposure was 2.3 mg/L; for episodic and cyclic exposure < 24 hours, an equation was derived incorporating the exposure duration. The limit derived to be protective of growth effects over persistent exposure was 4.8 mg/L; for episodic and cyclic exposure < 24 hours, the limit is based upon the intensity and hourly duration of the exposure. A generic larval recruitment model was used to determine the exposure conditions and DO concentrations that would allow adequate recruitment. Implementation of the criterion allows for periods of DO below the criterion, even for the persistent exposure scenario, in recognition of the evidence that many organisms can adapt to short periods of hypoxia. This approach was entirely based upon laboratory findings but was supported in part by field observations. It is an example of one approach that could be used to derive DO criteria for regions such as the Terrebonne basin. Laboratory data would need to be assembled for species representing the freshwater and mixed sites in the Terrebonne basin, and the data for the saltwater species used in the Virginian Province example would need to be evaluated for applicability to the saline sites in the Terrebonne basin. The DO data and biological data obtained during this study could potentially be used for verification.

6.2 Definition of a lower DO standard, potentially time dependent

Results of the present study indicate that nonattainment of a DO standard of 5 mg/L for freshwater areas and 4 mg/L for estuaries does not result in significantly impaired biological communities. Definition of a lower DO standard could be supported by a thorough evaluation of biological associations with DO concentrations. However, duration of exposure to depressed DO concentrations is an important factor. Because most of the water bodies considered in this study are relatively shallow (or have shallow edge habitat that is highly productive), stratification effects typically observed in deeper water do not appear significant to these areas.

The magnitude and duration of DO excursions that could occur and still support the desired aquatic communities is a complex question. At all fifteen reference sites, DO concentrations were above 2 mg/L with only a few exceptions that lasted for an hour to several hours. An examination of the aggregated CDF data reveals that approximately 90 percent of the time, the average DO was at or above approximately 3.2 to 4.1 mg/L for the freshwater and mixed salinity sites (Figures 6.1 and 6.2) and always at or above 4 mg/L for the saline sites (Figures 6.3 and 6.4).

Large diel swings in DO are typical during the summer season. Therefore, use of an average concentration to be attained over a predetermined duration is supported by the results of this study which have shown that although depression of DO occurs, it is for a limited time and biological communities do not appear to be significantly altered. It is likely that the resident aquatic organisms are capable of recovery and are adapted to such depression of DO levels.

6.3 Use of Indicator Species

A preliminary evaluation of indicator species sensitive to dissolved oxygen indicates that sufficient data are available to utilize in biological assessments and for the potential development of a biological index of dissolved oxygen tolerance. A summary of the potential for identifying benthic indicator species and fish indicator species is presented below.

6.3.1 Benthic Indicator Species

Most of the published literature on the effects of hypoxia on benthic invertebrates has focused on estuarine and marine environments. For freshwater benthic invertebrates, a comprehensive study of the associations of taxa and species with DO is provided by Rankin (2004).

Diaz and Rosenberg (1995) conducted a comprehensive review of the ecological effects of hypoxia on marine benthos. In general, polychaetes are the most tolerant taxa, followed by bivalves, and then crustaceans. Echinoderms and crustaceans are more sensitive to low dissolved oxygen and are rarely found in hypoxic areas.

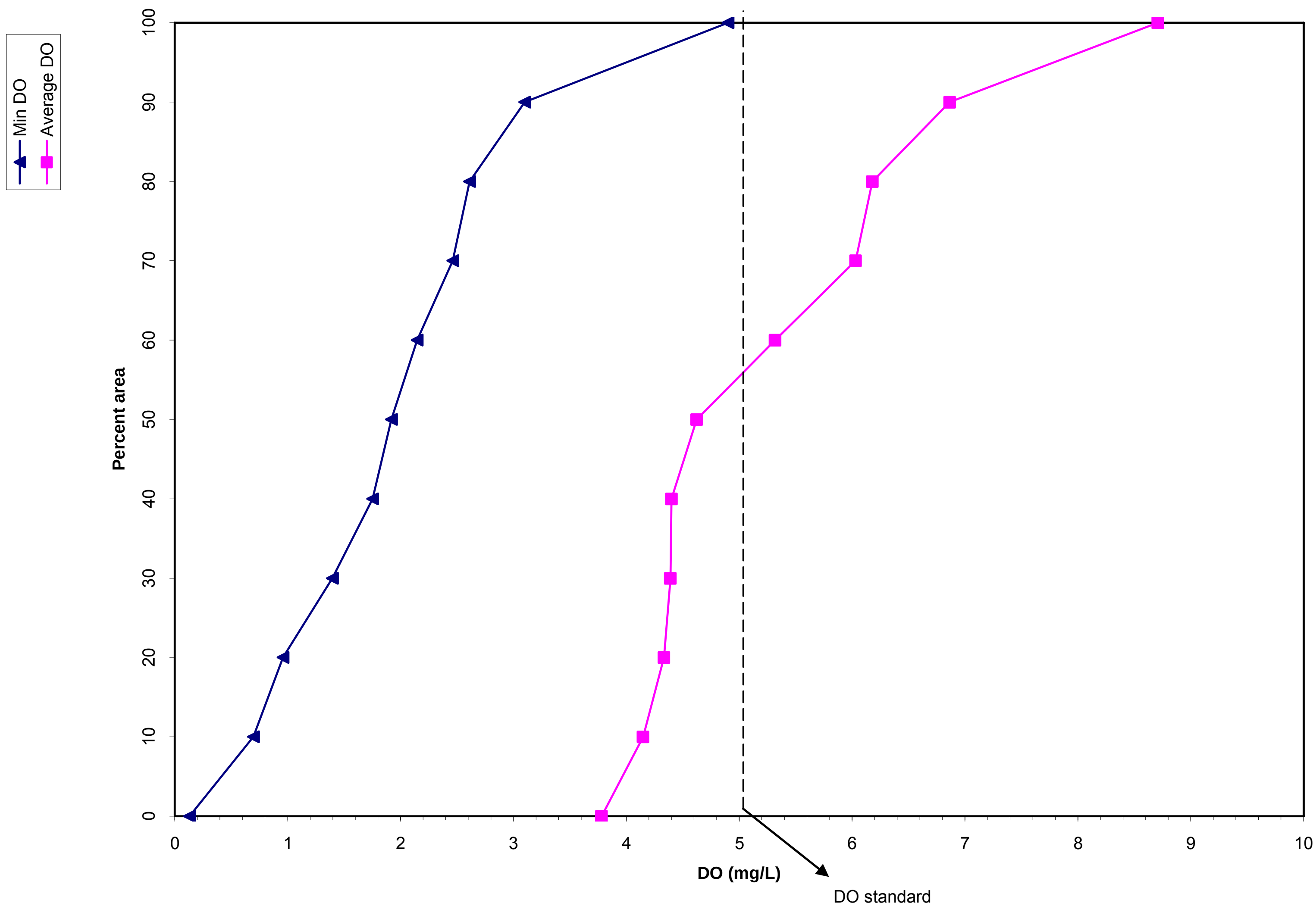

Figure 6-1. Cumulative Distribution Function for Minimum and Average DO Concentrations at Locations C-1 through C-10, Summer 2005

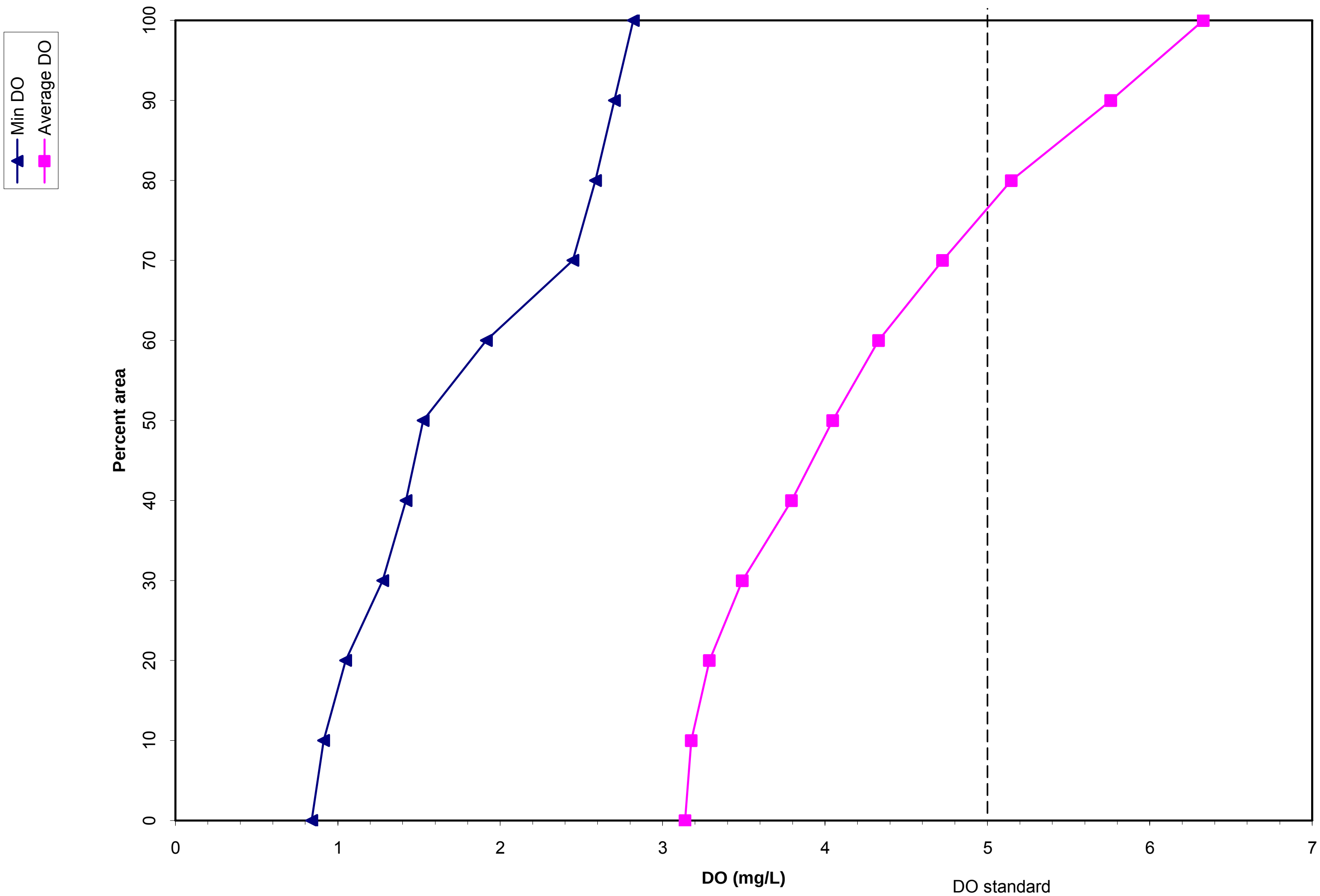

Figure 6-2. Cumulative Distribution Function for Minimum and Average DO Concentrations at Locations C-1 through C-10, Summer 2006

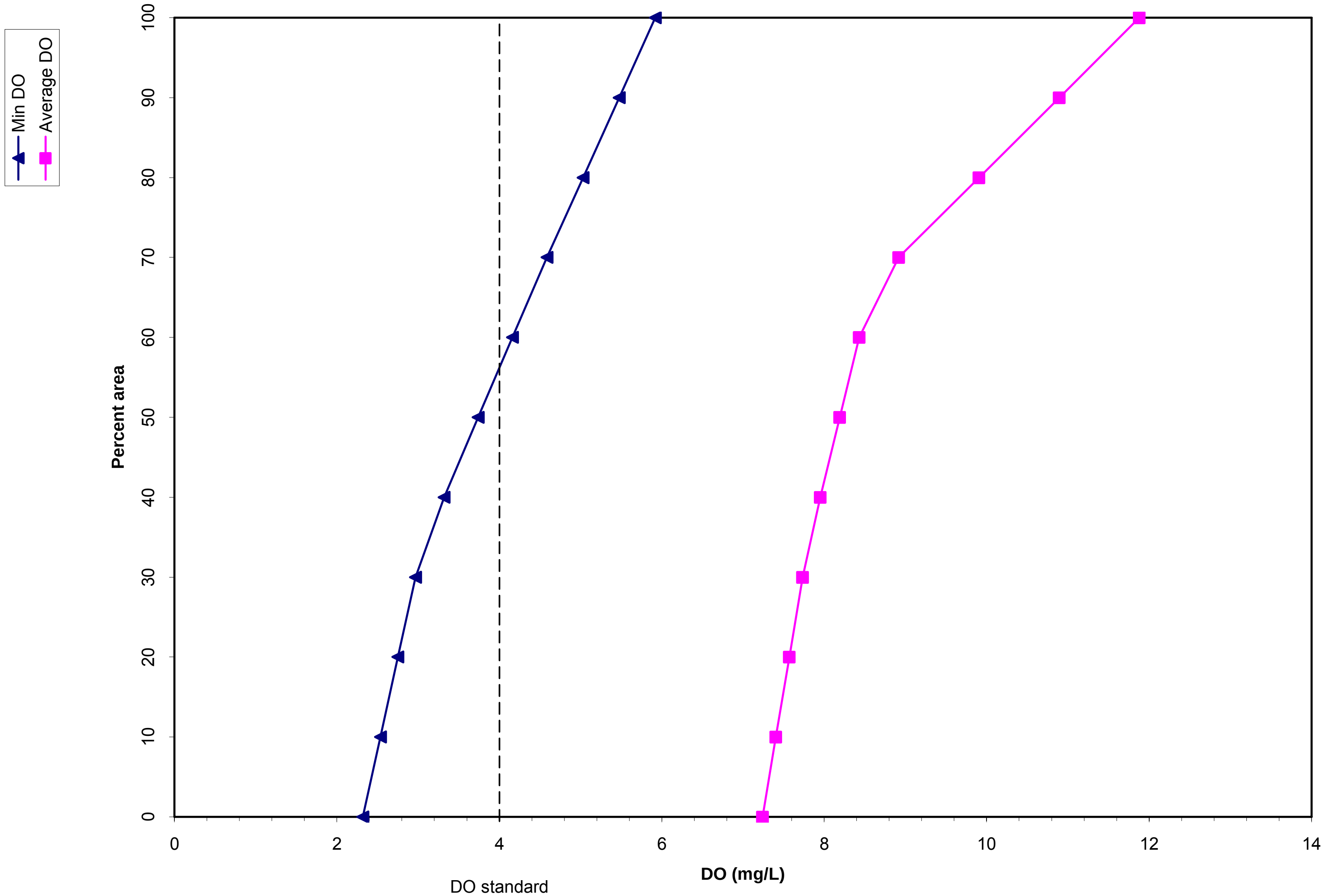

Figure 6-3. Cumulative Distribution Function for Minimum and Average DO Concentrations at Locations C-11 through C-15, Summer 2005

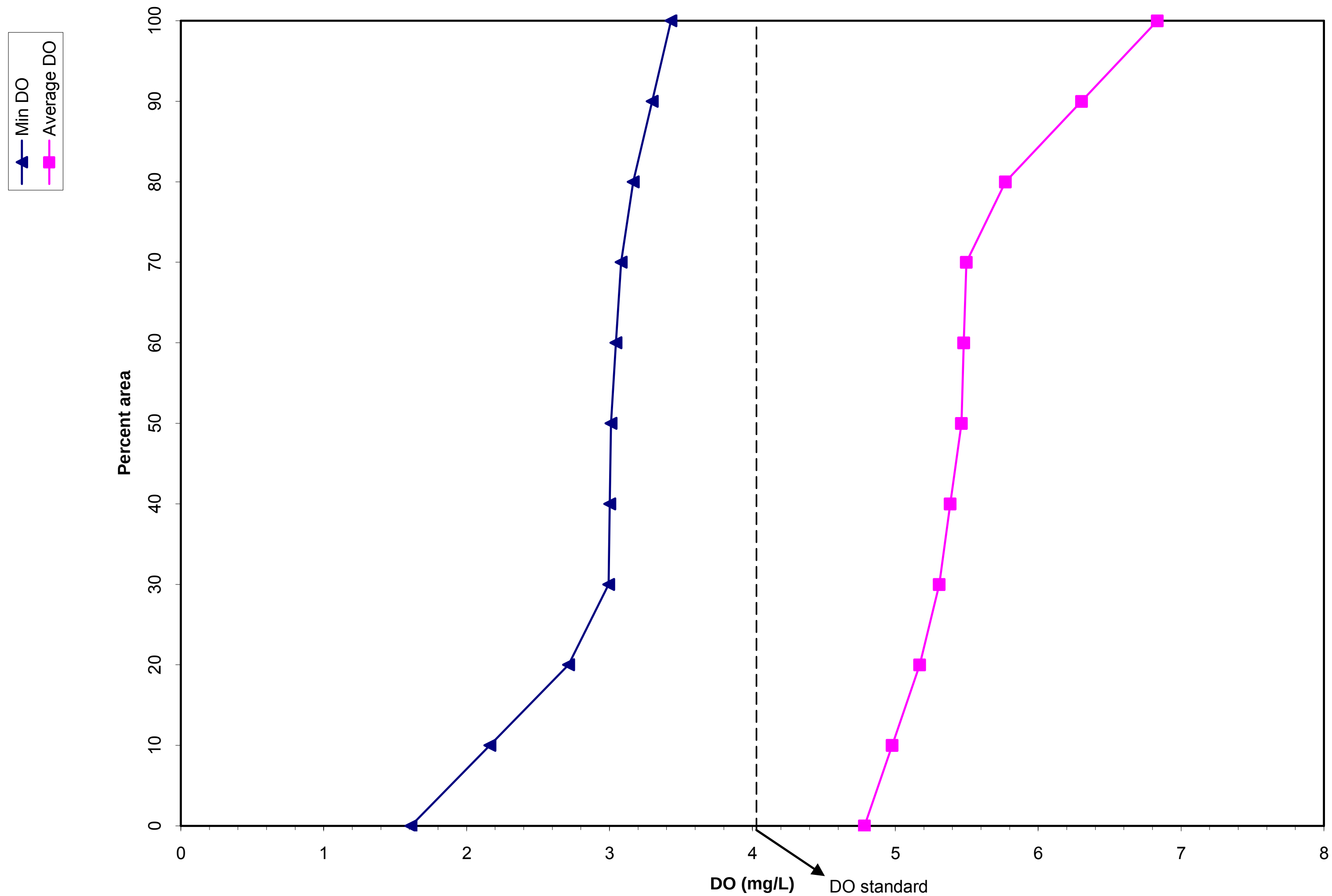

Figure 6-4. Cumulative Distribution Function for Minimum and Average DO Concentrations at Locations C-11 through C-15, Summer 2006

In the Chesapeake Bay, macrobenthic infaunal communities in areas of hypoxia (< 2 mg/L) were characterized by lower species diversity, lower biomass, a lower proportion of deep-dwelling biomass, and alteration in community composition (Dauer et al. 1992). These areas also had higher dominance of opportunistic species (e.g., euryhaline polychaetes) and lower dominance of equilibrium species (long-lived species such as bivalves and maldanid polychaetes found in undisturbed or unstressed habitats).

Ritter and Montagna (1999) collected benthic macroinfauna samples from normoxic and hypoxic regions of Corpus Christi Bay, Texas. Under hypoxic conditions, benthic biomass decreased 12-fold, and abundance and diversity decreased 5-fold. Dominant species patterns shifted as oxygen levels declined from 5 mg/L to < 1 mg/L. Tolerant taxa included the polychaete *Streblospio benedicti* and oligochaetes. Based on the statistical models of benthic response, biomass, abundance, and diversity exhibited a lag response at < 3 mg/L and increased exponentially from 3 mg/L to 6 mg/L. The breakpoint between normoxic and hypoxic benthic communities appears to be 3 mg/L (Ritter and Montagna 1999).

A summary of the Terrebonne Basin freshwater benthic macroinvertebrate species most sensitive to low dissolved oxygen and the occurrence at sites sampled during this study is provided in Table 6-1. Tolerance values were obtained from Rankin (2004) and represent weighted dissolved oxygen values where the weighting is done based on the relative abundance of a specific organism at a site. The minimum DO value from each station was used to generate a weighed parameter value as the best indicator of stress conditions which was then paired with taxa or species abundances collected from the same sites during the same summer period. Higher tolerance values are indicative of intolerant (sensitive) species to low dissolved oxygen. The database used to define biological associations with DO consisted of only taxa which had more than 100 data points (about 20 stations) that also had biological and DO data collected concurrently. A tolerance value of >5.6 weighted mean dissolved oxygen was selected to represent benthic macroinvertebrate species, observed during the present study, that were most sensitive. Although the tolerance values are for benthic macroinvertebrate species collected from Ohio waters, it is likely that similar trends in benthic tolerance to dissolved oxygen would exist for Louisiana.

A summary of the Terrebonne Basin saltwater benthic macroinvertebrate species most sensitive to low dissolved oxygen and the occurrence at sites sampled during this study is provided in Table 6-2. Ranked tolerance data were not available for saltwater fish species. Laboratory values were primarily selected from USEPA (2000) based on the limited data available for the species collected during this study.

Table 6-1. Terrebonne Basin Freshwater Benthic Macroinvertebrates Most Sensitive to Low DO

Species	Tolerance or Lab Value	Reference	Site Occurrence
Caenis diminuta	6.3501 (sp.)	Rankin (2004)	C-1 through C-10
Caenis sp.	6.3501	Rankin (2004)	C-6
Callibaetis sp.	6.0461	Rankin (2004)	C-2, C-3, C-5, C-6, C-9, C-10
Cambaridae	5.7087	Rankin (2004)	C-10
Chironomus sp.	6.4230	Rankin (2004)	C-8
Cryptochironomus sp.	6.2207	Rankin (2004)	C-1, C-2, C-4, C-5, C-8, C-10
Dicrotendipes sp.	6.8674	Rankin (2004)	C-4, C-6, C-10
Gammarus sp.	5.6962 (*fasciatus*) 2.2 mg/liter mortality threshold (*pseudolimnaeus*) 4.3 mg/liter mortality threshold (*fasciatus*)	Rankin (2004) Davis (1975) Davis (1975)	C-4, C-5, C-7, C-10
Glyptotendipes sp.	5.9360	Rankin (2004)	C-1 through C-10
Hexagenia sp.	6.5506	Rankin (2004)	C-4
Hydra sp.	6.1653 6.0859 (*pilosella*)	Rankin (2004) Rankin (2004)	C-7
Larsia sp.	6.0753	Rankin (2004)	C-2, C-3, C-5, C-6
Lirceus sp.	6.6320	Rankin (2004)	C-7
Polypedilum fallax gr.	6.0621	Rankin (2004)	C-2
Pseudochironomus sp.	6.0726	Rankin (2004)	C-2
Stenacron interpunctatum	6.3213 (sp.)	Rankin (2004)	C-4
Tanytarsus sp.	6.4548	Rankin (2004)	C-1, C-5, C-6, C-7, C-8, C-10

Most sensitive taxa are those with tolerance >5.6 value.

Table 6-2. Terrebonne Basin Saltwater Benthic Macroinvertebrates Most Sensitive to Low DO

Species	Tolerance or Lab Value	Reference	Site Occurrence	Comments
Ophiuroidea	NA	Dauer et al. (1992)	C-12	Equilibrium (sensitive) species
Palaemonetes pugio	1.53 (SMAV LC5/LC50, juvenile) 1.24 (SMAV - 24 hr LC50, <24 hr old larvae) 1.58 (SMAV - 96 hr LC50, <24 hr old larvae)	USEPA (2000) USEPA (2000) USEPA (2000)	C-11, C-13, C-14	
Palaemonetes sp.	1.53 (SMAV LC5/LC50, juvenile)*	USEPA (2000)	C-12	*Value is for *Palaemonetes pugio*
Ampelisca sp.	<0.9 (SMAV LC50, juvenile)*	USEPA (2000)	C-11, C-15	*Value is for *Ampelisca abdita*
Americamysis bahia	1.27 (SMAV LC50, juvenile) 2.4-4.17 (NOEC, <48 hr old juvenile)	USEPA (2000) USEPA (2000)	C-11, C-12	

SMAV Species Mean Acute Value. SMAV is a geometric mean.

NOEC No observed effect concentration.

* An asterisk is placed next to the item to which the comment refers.

NA Not available.

6.3.2 Fish Indicator species

As DO concentrations decline, overall fish abundance and species richness decrease (Breitburg 2002). Several studies have repeatedly shown that abundance and diversity of demersal fishes are particularly decreased as oxygen concentrations decline. Extremely depauperate fish populations occur in bottom waters with DO less than approximately 2 mg/L (Breitburg 2002).

In southwest Arkansas, Killgore and Hoover (2001) evaluated freshwater fish species composition along an environmental gradient of dissolved oxygen concentrations ranging from 0.2 to 7.5 mg/L. In the lower hypoxic reach of the bayou, fish species richness was low (<8 species per sample), while species richness was relatively high (>13 species per sample) in the upper and middle reaches of the bayou. A significant positive correlation between fish species richness and dissolved oxygen was reported. At DO below 0.5 mg/L, species richness, abundance, and size of fish were substantially reduced suggesting a threshold response level. Gars, topminnows, and small backwater sunfishes were reported from areas with low DO concentrations, while sunfishes, darters, and larger benthic fishes appeared to avoid hypoxic waters. Fish species adapted for aerial (gars and bowfin) and surface film respiration (topminnows) dominated the fish assemblage in hypoxic waters (Killgore and Hoover 2001).

A summary of the Terrebonne Basin freshwater fish species most sensitive to low dissolved oxygen and the occurrence at sites sampled during this study is provided in Table 6-3. Laboratory values of dissolved oxygen are lethal levels obtained from Doudoroff and Shumway (1970) and critical minimum concentrations obtained from Smale and Rabeni (1995). Tolerance values were obtained from Rankin (2004) and represent weighted dissolved oxygen values where the weighting is done based on the relative abundance of a specific organism at a site. A tolerance value of >5.6 weighted mean dissolved oxygen was selected to represent fish species that were most sensitive. Although the tolerance values are for fish species collected from Ohio waters, it is likely that similar trends in fish tolerance to dissolved oxygen would exist for fish collected in Louisiana.

A summary of the Terrebonne Basin saltwater fish species most sensitive to low dissolved oxygen and the occurrence at sites sampled during this study is provided in Table 6-4. Ranked tolerance data were not available for saltwater fish species. Laboratory values were selected from USEPA (2000) based on the limited data available for the species collected during this study.

6.4 Development of tiered aquatic life uses and corresponding DO criteria

The Clean Water Act establishes the objective of restoring and maintaining the chemical, physical, and biological integrity of U.S. waters and the water quality standards (WQS) program as a means of implementing this objective. Water quality standards include three aspects: the designated use of the water body, the criteria necessary to protect that use, and an antidegradation policy. The “use” of a waterbody is a description of its role in the aquatic and human environments (e.g., primary contact recreation, drinking water supply, etc.). Determining the appropriate designated use, including the kinds of aquatic life the water body will support, is critically important in determining the water quality criteria that should apply to protect that use.

Biological information can be used to better define designated aquatic life uses in water quality standards by “tiering” uses. Ideally, the use designation process allows for differentiated levels of protection so that managers can develop the most appropriate water quality standards to protect those specific uses. Louisiana does have seven types of designated uses for surface waters, including the use of “fish and wildlife propagation.” Within this category, a subcategory of “limited aquatic wildlife use” has been established. However, the current Louisiana water quality standards for DO are not specifically linked to either of these uses. The DO standard for fresh waters and coastal marine waters is 5 mg/L, while the DO standard for estuarine waters is 4 mg/L, without mention of a different standard depending upon the use designation.

Table 6-3. Terrebonne Basin Freshwater Fishes Most Sensitive to Low DO

Scientific Name	Common Name	Tolerance or Lab Value	Reference	Site Occurrence	Comments
Aplodinotus grunniens	Freshwater Drum	5.6642 4.3 mg/L	Rankin 2004 Doudoroff & Shumway 1970	C-1, C-2, C-4, C-6, C-7, C-8	
Dorosoma cepedianum	Gizzard Shad	5.8202	Rankin 2004	C-1, C-2, C-3, C-4, C-5, C-6, C-8, C-9, C-10	
Ictalurus punctatus	Channel Catfish	6.3442 0.8-2.0 mg/L	Rankin 2004 Doudoroff & Shumway 1970	C-2, C-4, C-7, C-8, C-9, C-10	
Lepomis gulosus	Warmouth Sunfish	5.7176 0.7-1.3 mg/L*	Rankin 2004 Doudoroff & Shumway 1970*	C-2, C-4	*Values are for Chaenobryttus gulosus.
Lepomis macrochirus	Common Bluegill	0.66 mg/L* 0.5-3.1 mg/L	Smale & Rabeni 1995* Doudoroff & Shumway 1970	C-1 through C-10	*Mean critical minimum DO concentration
Lepomis megalotis	Longear Sunfish	6.0558 / 0.68 mg/L*	Rankin 2004 Smale & Rabeni 1995*	C-1, C-2, C-4, C-8	*Mean critical minimum DO concentration
Micropterus salmoides	Largemouth Bass	5.9103 0.70 mg/L* 0.8-3.1 mg/L	Rankin 2004 Smale & Rabeni 1995b* Doudoroff & Shumway 1970	C-1, C-2, C-3, C-4, C-5, C-6, C-7, C-8, C-10	*Mean critical minimum DO concentration
Pomoxis annularis	White Crappie	5.8141	Rankin 2004	C-1	
Pomoxis nigromaculatus	Black Crappie	0.4-0.5 mg/L 6.6345 1.0-4.3 mg/L	Doudoroff & Shumway 1970 Rankin 2004 Doudoroff & Shumway 1970	C-2, C-3, C-4, C-5, C-6, C-7, C-8, C-10	
Pylodictis olivaris	Flathead Catfish	5.8245	Rankin 2004	C-7, C-8	

Most sensitive taxa are those with tolerance value >5.6.

GMAV Genus Mean Acute Value. GMAV is a geometric mean.

* An asterisk is placed next to the item to which the comment refers.

Table 6-4. Terrebonne Basin Saltwater Fishes Most Sensitive to Low DO

Scientific Name	Common Name	Lab Value	Reference	Site Occurrence	Comments
Anchoa mitchilli	Bay Anchovy	1.6 mg/L and 2.8 mg/L (12 hr LC50, larvae)	USEPA 2000	C-8, C-11, C-12, C-13, C-14, C-15	
Brevoortia patronus	Gulf Menhaden	1.53 (GMAV LC5/LC50, juvenile)	USEPA 2000	C-12	Value is for *Brevoortia tyrannus*.
Chasmodes bosquianus	Striped Blenny	2.50 (GMAV - 24 hr LC50, larvae) 2.07 mg/L (1 hr 5% mortality, larvae)	USEPA 2000	C-13	
Gobioides broussoneti	Violet Goby (E)	1.30 (GMAV - 24 hr LC50, larvae)* 1.02 mg/L (1 hr 15% mortality, larvae)*	USEPA 2000*	C-12, C-13, C-14	*Value is for *Gobiosoma bosc*.
Paralichthys lethostigma	Southern Flounder	1.59 mg/L (72 hr LC50, juvenile/adult)	USEPA 2000	C-12	Value is for *Paralycthys denatus*.
Sciaenops ocellatus	Red Drum	1.76 (GMAV - 24 hr LC50, larvae)	USEPA 2000	C-14	
Syngnathus louisianae	Chain Pipefish	1.17 (GMAV LC5-LC50, juvenile)	USEPA 2000	C-12	Value is for *Syngnathus fuscus*.

All organisms are estuarine-marine species unless otherwise notes.

E Estuarine.

GMAV Genus Mean Acute Value. GMAV is a geometric mean.

* An asterisk is placed next to the item to which the comment refers.

Tiered aquatic life uses (TALUs) are bioassessment-based statements of expected biological condition in specific waterbodies. The use of biological information in establishing designated uses for aquatic life accounts for the variability found in natural systems. A scientific model, known as the Biological Condition Gradient, reflects the observation that there is a continuum of biological responses to increasing levels of stressors (analogous to a dose-response relationship in classical toxicology). TALU, supported by appropriate criteria, can define the “gray area” across this continuum ranging from “totally pristine” to “completely degraded” and allow the appropriate management actions to be implemented to obtain the desired level of protection. Graduated levels of protection prevent unacceptably degraded conditions as well as unnecessarily overprotective conditions.

Several states have adopted tiered aquatic life use statements in their water quality standards. Texas, for example, has had such tiered uses identified since 1984 (Table 6.5). Texas’ current water quality standards identify numeric dissolved oxygen criteria and include narrative aquatic life attributes, and numeric biological criteria have been developed for assessing both fish and benthic macroinvertebrate communities in wadeable streams. Biological criteria have not been adopted to date in Texas for water bodies other than wadeable streams.

Other states (e.g., Maine, Ohio, New Jersey, Vermont) have either developed or are considering TALU. Common elements of these programs include the use of biological information as the basis for the use designations, numeric biocriteria for each use, and development of tiers based on data from extensive monitoring programs.

Under the TALU approach, Louisiana could further distinguish between the “fish and wildlife propagation” use and the “limited aquatic wildlife use,” adopting different DO criteria for each. For example, DO, habitat, and biological data from most of the sites studied during the present investigation seem to fall within the Intermediate and High Use Aquatic Life Subcategories used by Texas. Additional refinement of TALU of Louisiana would be necessary to accommodate the wide variation observed for both DO concentrations and biological communities.

6.5 Summary

The results of the this investigation indicated that the existing DO criteria for reference locations in the waterbodies in the Terrebonne basin are not attained, especially if applied strictly as single “not to exceed” values. It should be noted that the current Louisiana water quality standards, however, do allow for naturally occurring variations for short periods, reflecting natural phenomena such as the diurnal DO fluctuation resulting from photosynthesis and respiration. The study locations were selected to be “least impacted”, and were characterized by reasonably healthy and diverse aquatic communities (albeit containing organisms tolerant of low DO). During the critical period, at freshwater and mixed salinity locations, the average DO did not meet the applicable standard of 5 mg/L from 55 to 75 of the time. At saline locations, the applicable standard of 4 mg/L was always met, based upon average DO. However, based upon minimum DO, the freshwater and mixed salinity locations never attained the standard and the saline locations did not attain the standard more than half the time. The refinement of DO criteria, especially for those waterbodies subject to the 5 mg/L standard, and especially since criteria attainment is currently based upon the minimum DO, thus appears warranted. It is likely that multiple approaches will be required to address refinement of DO criteria in south Louisiana water bodies such as the Terrebonne Basin.

Additionally, because excess nutrient loading and alterations to the nitrogen cycle are linked to hypoxia via eutrophication, monitoring of nutrient parameters is an important consideration for determining DO criteria.

Table 6-5. Aquatic Life Subcategories in Texas Water Quality Standards

Aquatic Life Use Subcategory	Dissolved Oxygen Criteria, mg/L			Aquatic Life Attributes					
	Freshwater mean/ minimum	Freshwater in Spring mean/ minimum	Saltwater mean/ minimum	Habitat Characteristics	Species Assemblage	Sensitive species	Diversity	Species Richness	Trophic Structure
Exceptional	6.0/4.0	6.0/5.0	5.0/4.0	Outstanding natural variability	Exceptional or unusual	Abundant	Exceptionally high	Exceptionally high	Balanced
High	5.0/3.0	5.5/4.5	4.0/3.0	Highly diverse	Usual asso- ciation of regionally expected species	Present	High	High	Balanced to slightly imbalanced
Intermediate	4.0/3.0	5.0/4.0	3.0/2.0	Moderately diverse	Some expected species	Very low in abundance	Moderate	Moderate	Moderately imbalanced
Limited	3.0/2.0	4.0/3.0	---	Uniform	Most regionally expected species absent	Absent	Low	Low	Severely imbalanced

Dissolved oxygen means are applied as a minimum average over a 24-hour period.

Daily minima are not to extend beyond 8 hours per 24-hour day. Lower dissolved oxygen minima may apply on a site-specific basis, when natural daily fluctuations below the mean are greater than the difference between the mean and minima of the appropriate criteria.

Spring criteria to protect fish spawning periods are applied during that portion of the first half of the year when water temperatures are 63.0 °F to 73.0 °F.

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7. References

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